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VTOL HANDLING QUALITIES CRITERIA STUDY THROUGH MOVING-BASE SIMULATION

R. L. McCORMICK

Cornell Aeronautical Laboratory

TECHNICAL REPORT AFFDL-TR-69-27

OCTOBER 1969

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AD 863818

VTOL HANDLING QUALITIES CRITERIA STUDY THROUGH MOVING-BASE SIMULATION

R. L. McCORMICK

FOREWORD

This report was prepared by the Norair Division of Northrop Corporation, Hawthorne, California under Subcontract S-68-38 to the Cornell Aeronautical Laboratory.

The work was performed under the sponsorship of the Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio from February 1968 to April 1969 as part of Part III of the VTOL Integrated Flight Control Systems Program (VIFCS), Contract AF 33(615)-3736, Project 698DC. The AFFDL project engineer was Mr. Wilfred Klotzback and the CAL project engineer was Mr. George Saunders.

Significant contributions as participating pilots in the program were made by Nello L. Infanti and Rogers E. Smith of Cornell Aeronautical Laboratory; Major Thomas H. Smith, Major David W. Thomas, and Captain Roy E. Palmer, Jr., of the United States Air Force Flight Test Center; and William W. Koepcke, Jr., of Northrop Corporation. An additional note of appreciation is extended to Robert B. Wilson of Northrop Corporation who performed the analog computer mechanizations.

Northrop Norair number NOR 69-7 has been assigned to this report for internal control.

This technical report has been reviewed and is approved.

C. B. Westbrook
Chief Control Criteria Branch
Flight Control Division
Air Force Flight Dynamics Laboratory

ABSTRACT

An investigation of VTOL longitudinal and lateral handling qualities in hovering and low-speed maneuvering flight was conducted on a moving-base simulator. The simulator included an external display, and the task performed by the participating pilots was a visual rather than an instrument task. Pertinent longitudinal and lateral stability derivatives were varied in a wide range of test configurations. Most of the cases investigated included the effects of steady winds and turbulence. For part of the program, stick force gradients existed on the simulator control stick; for part of the program, they did not.

For most of the cases, the pilot selected optimum control sensitivities. In all cases a pilot rating and pilot comments were given. Other data resulting from the simulations include probability density and power spectral density analyses. Pilot performance for part of the task also was calculated.

It appeared that the most significant parameters affecting pilot rating were the drag parameters because of the large attitude changes that resulted when compensating for steady wind and when maneuvering. Speed stability parameters did not seem to have a clear-cut effect on handling qualities.

Steady winds and gusts had a strong influence on pilot acceptability when high drag factors were present. Stick force gradients did not, when steady winds were absent.

Control sensitivity seemed to be more a matter of personal pilot preference than the configuration.

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g	Acceleration due to gravity, 32.2 ft/sec^2
I_x, I_y, I_z	Aircraft moments of inertia in roll, pitch, and yaw, slug-ft^2
K_{θ_D}	Display pitch drive position gain
$K_{\dot{\theta}_D}$	Display pitch drive velocity gain
K_{θ_M}	Motion base pitch drive position gain
$K_{\dot{\theta}_M}$	Motion base pitch drive velocity gain
K_{ϕ_D}	Display roll drive position gain
$K_{\dot{\phi}_D}$	Display roll drive velocity gain
K_{ϕ_M}	Motion base roll drive position gain
$K_{\dot{\phi}_M}$	Motion base roll drive velocity gain
K_{ψ_D}	Display yaw drive position gain
$K_{\dot{\psi}_D}$	Display yaw drive velocity gain
K_{ψ_M}	Motion base yaw drive position gain
$K_{\dot{\psi}_M}$	Motion base yaw drive velocity gain
L	Rolling moment / I_x, rad/sec^2
L_p	$\partial L/\partial p$
L_v	$\partial L/\partial v$
L_δ	$\partial L/\partial \delta_a$
L_ϕ	$\partial L/\partial \phi$
m	Mass of aircraft, slugs
M	Pitching moment/I_y, rad/sec^2
M_q	$\partial M/\partial q$
M_u	$\partial M/\partial u$

LIST OF SYMBOLS (Continued)

M_δ	$\partial M/\partial \delta_e$
M_θ	$\partial M/\partial \theta$
N	Yawing moment / I_z, rad/sec^2
N_r	$\partial N/\partial r$
N_v	$\partial N/\partial v$
N_δ	$\partial N/\partial \delta_r$
p	Roll rate, rad/sec
$P(L_c)$	Probability density of roll control input
$P(M_c)$	Probability density of pitch control input
$P(\delta_a)$	Probability density of roll control stick travel
$P(\delta_e)$	Probability density of pitch control stick travel
PR	Pilot rating
q	Pitch rate, rad/sec
r	Yaw rate, rad/sec
s	Laplace operator, 1/sec
SAS	Stability augmentation system
T_E	M_θ/M_q, sec
u	Velocity along x body axis
u_{gust}	Gust velocity along x body axis
v	Velocity along y body axis
v_{gust}	Gust velocity along y body axis
w	Velocity along z body axis
W_x	Wind component in X earth axis
W_y	Wind component in Y earth axis
X	Force along x body axis / m, ft/sec^2; north-south earth axis
X_u	$\partial X/\partial u$
Y	Force along y body axis / m, ft/sec^2; east-west earth axis

LIST OF SYMBOLS (Continued)

Y_v	$\partial Y/\partial v$
Z	Force along z body axis / m, ft/sec^2; vertical earth axis
Z_w	$\partial Z/\partial w$
Z_δ	$\partial Z/\partial \delta_c$
δ_a	Roll control stick travel, inches
δ_c	Collective lever travel, inches
δ_e	Pitch control stick travel, inches
δ_r	Yaw control pedal travel, inches
ζ	Damping ratio of airframe second-order oscillation
θ	Pitch Euler angle, radians
θ_D	Display pitch angle
θ_M	Motion base pitch angle
λ	Real root in airframe cubic when cubic includes second-order term
$\lambda_{\theta_{1,2,3}}$	Real root in airframe longitudinal cubic when cubic has no second-order term
$\lambda_{\phi_{1,2,3}}$	Real root in airframe lateral cubic when cubic has no second-order term
σ	Standard deviation
σ_q	RMS value of q
σ_u	RMS value of u
σ_x	RMS value of x
σ_{δ_e}	RMS value of δ_e
σ_θ	RMS value of θ
ϕ	Roll Euler angle, radians
ϕ_D	Display roll angle
ϕ_M	Motion base roll angle

LIST OF SYMBOLS (Continued)

$\Phi(\delta_a)$	Power spectral density of roll control stick travel, in^2/Hz
$\Phi(\delta_e)$	Power spectral density of pitch control stick travel, in^2/Hz
ψ	Yaw Euler angle, radians
ψ_D	Display yaw angle
ψ_M	Motion base yaw angle
ω_D	Damped frequency of airframe second-order oscillation, rad/sec
ω_n	Natural frequency of airframe second-order oscillation, rad/sec

SECTION I

INTRODUCTION

The simulation reported herein was conducted to provide experimental data for establishing longitudinal and lateral-directional handling qualities specifications for VTOL aircraft in the hover and low-speed maneuvering range. The experiments were performed on the Northrop Norair Rotational Flight Simulator.

A description of the simulator and data pertaining to the motion and display drive systems are presented in Section II. The airframe equations of motion are presented in Section III.

A description of the piloting tasks is given in Section IV. For purposes of reporting results, the entire program is considered to consist of three simulations and an additional experiment reported on in Appendix IV. In the first simulation, 58 configurations were evaluated in which the primary axis of evaluation was longitudinal. For these, the lateral, directional, and height dynamics were held constant. Similarly, 58 lateral configurations were also evaluated with the dynamics of the other axes held constant. The second simulation consisted of a number of repeat configurations and six new configurations. In the third simulation, 60 configurations were evaluated in which the dynamics of both the longitudinal and lateral axes were varied with each configuration. Again, the directional and height dynamics were held fixed.

The stability derivatives of all the configurations evaluated are presented in Section V. The results of the simulations are given in Section VI. For each case a pilot rating was assigned the configuration by the evaluating pilot. In most cases, the control sensitivity of the axis under evaluation was selected by the pilot. For a few of the cases in the third simulation, the control sensitivities were fixed. In addition to pilot ratings and control sensitivities, a performance measure of part of the pilots' task is presented. Also given are probability density plots of control activity and control usage for some of the cases, and power spectral density plots of control activity for these cases. A discussion of the results is presented in Section VII.

Resumes covering the pertinent experience of the participating pilots are presented in Appendix I. Appendix II contains pilot comments for most of the cases tested. For a few of the cases, probability density plots are given in Appendix III for control stick travel and for control input. Power spectral density plots of stick travel for these cases are also presented. Appendix IV contains the results of a program conducted to compare results obtained by United Aircraft Research Laboratories on a fixed-base simulator with those obtained by the same pilot on a different fixed-base simulator and then on a moving-base simulator.

SECTION II

FLIGHT SIMULATOR DATA

The program was conducted in the Northrop Norair rotational three-axis flight simulator (see Figures 1 and 2). This device has been developed to simulate flight tasks requiring strong visual cues for the pilot. The external world display was adapted from the DeFlorez point light source technique.

The simulator consists of a cockpit with rotational motion which is located within a 12-foot-radius hemispherical screen. A point light source projection system produces a six-degree-of-freedom wide-angle visual display to the pilot. The display is presented with appropriate perspective, size, and position relative to the observer, thus simulating the visual world as viewed from any desired position in space. The wide coverage of the visual display, both laterally and vertically, presents a continuous world to either side as well as above and below the pilot.

Limit switches on the motion and display systems were set so that the simulator would reset before the physical limits of travel were reached. These limits were set at the following approximate positions: ±10-degree cockpit pitch motion; ±19-degree display pitch motion; ±13-degree cockpit roll motion; ±18-degree display roll motion; and ±8-degree cockpit yaw motion. The display yaw motion was continuous.

Limiters on the analog computers were set just inside of the above limit switches. These limiters normally prevented the cockpit and the display from resetting due to triggering the limit switches. However, if the simulator were maneuvered rapidly enough against the computer limiters, they could be exceeded and the limit switches then would cause a reset. If this happened, the system then would be put in the original initial conditions and the task continued at that point.

The transparency used in the program was circular and scaled at 150:1. Limit switches were also set for translation of the display. They were set to provide a simulated radius of travel of approximately 245 feet and a simulated altitude range of 120 feet. There was no translation of the cockpit.

The apportioning of computed motion between cockpit and display was determined by the frequency of motion through washout filters. High-frequency motion was largely directed to the cockpit; low-frequency motion to the display. A sample time history of the simulator motions is given in Figure 3. The cockpit also was tilted to simulate translational acceleration.

Block diagrams of the motion system are presented in Figures 4 through 6. Frequency response plots for the simulator cockpit and the visual display are presented in Figures 7 through 12.

A minimum of cockpit instrumentation was provided because the tasks were mainly visual. However, an altimeter was necessary for determining height, and an airspeed indicator and attitude indicator also were provided.

The equations for the motion system drives are presented in Section III.

For part of the program there were no stick force gradients. For the cases that used stick force gradients, the values were approximately 1.3 pounds/inch in pitch control and 1.0 pound/inch in roll control. A rudder force gradient of approximately 6.4 pounds/inch was used throughout. The stick deflection available were ±5 inches both longitudinally and laterally. The rudder pedal travel was ±2 inches.

The cockpit height control was of the throttle type, although it is referred to as the "collective" in this report.

The following data were recorded on strip-chart recorders:

Roll control stick travel and this quantity squared.

Pitch control stick travel and this quantity squared.

Yaw control pedal travel and this quantity squared.

Collective lever travel.

Altitude.

Computed pitch angle.

Pitch angle feedback signals from the display and from the motion base.

Computed roll angle.

Roll angle feedback signals from the display and from the motion base.

Pitch control input to the airframe due to control deflection, rate feedback, and attitude feedback.

Roll control input to the airframe due to control deflection, rate feedback, and attitude feedback.

Earth coordinates taken as feedback signals from the display.

Body-axis velocities u and v.

Body angular rates p and q.

Sine and cosine of aircraft yaw angle.

The following data were recorded on magnetic tape:

Earth coordinates taken as feedback signals from the display.

Altitude.

Computed pitch and roll angles.

Roll, pitch, yaw, and altitude cockpit control travels.

Body angular velocities p and q.

Voice.

For the first simulation, body-axis velocity u and pitch angle feedback signals from the display and from the motion base were recorded for the longitudinal evaluations. Body-axis velocity v and the roll angle feedback signals were recorded for the lateral evaluations.

For the second and third simulations, the pitch control and roll control inputs to the airframe from control deflections rate feedback, and attitude feedbacks were recorded. To obtain the probability density and power spectral density plots of these signals for the first simulation cases, the signals were recorded later from their component signals.

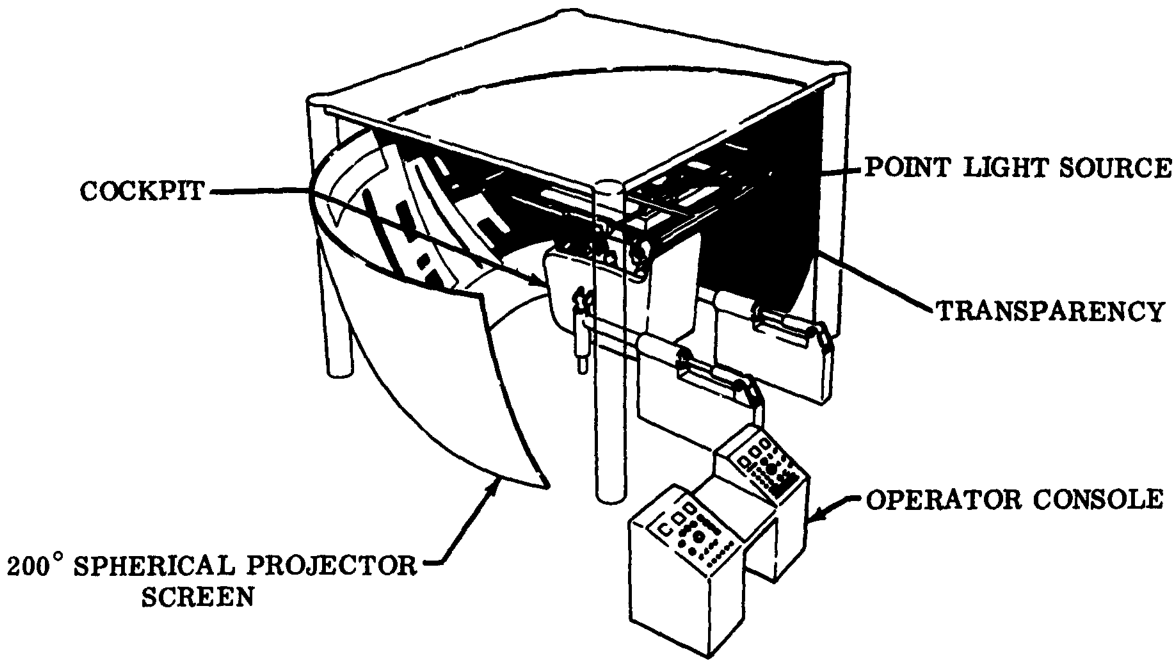


FIGURE 1. ROTATIONAL 3-AXIS FLIGHT SIMULATOR COMPONENTS

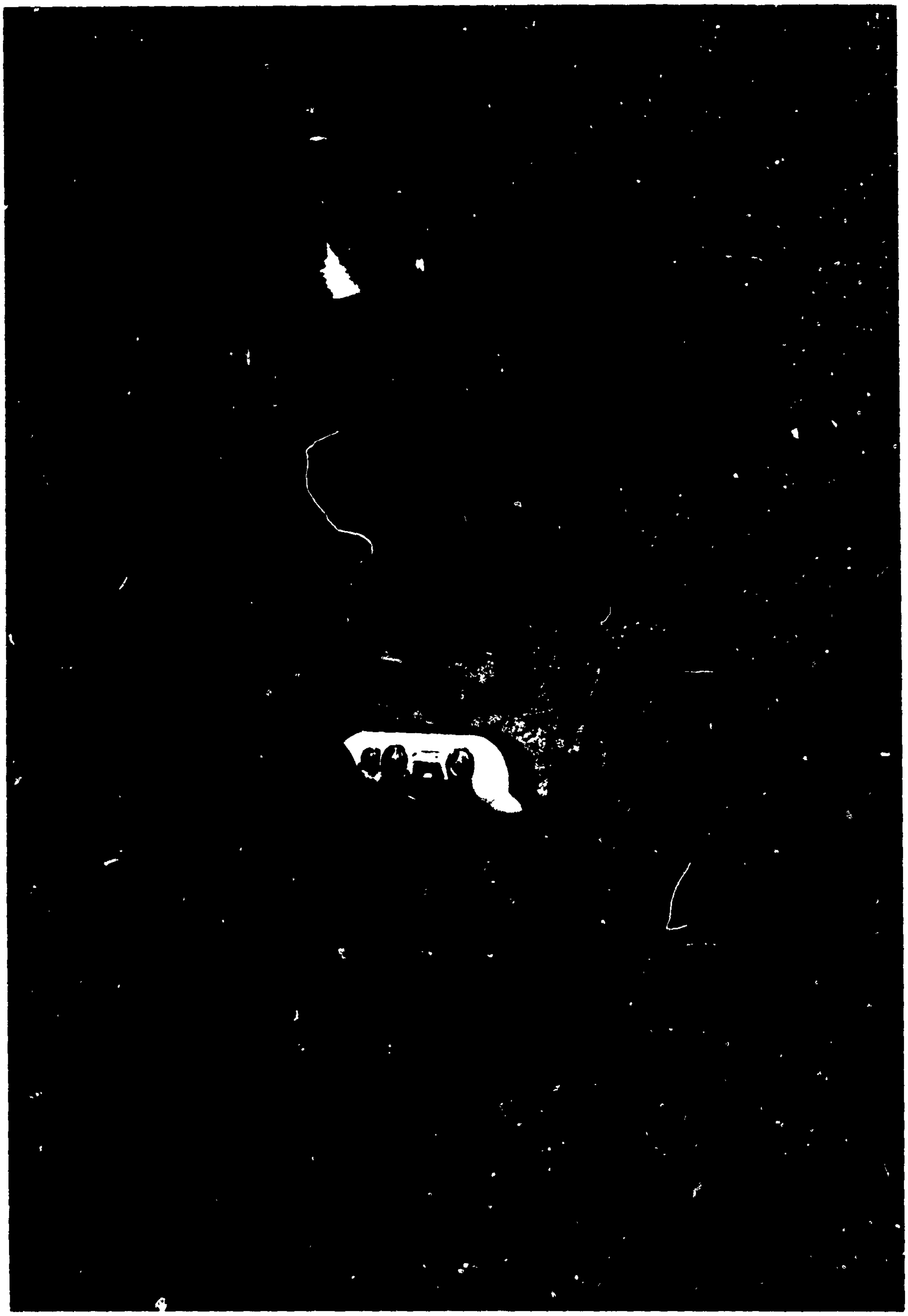


FIGURE 2. ROTATIONAL 3-AXIS FLIGHT SIMULATOR DISPLAY

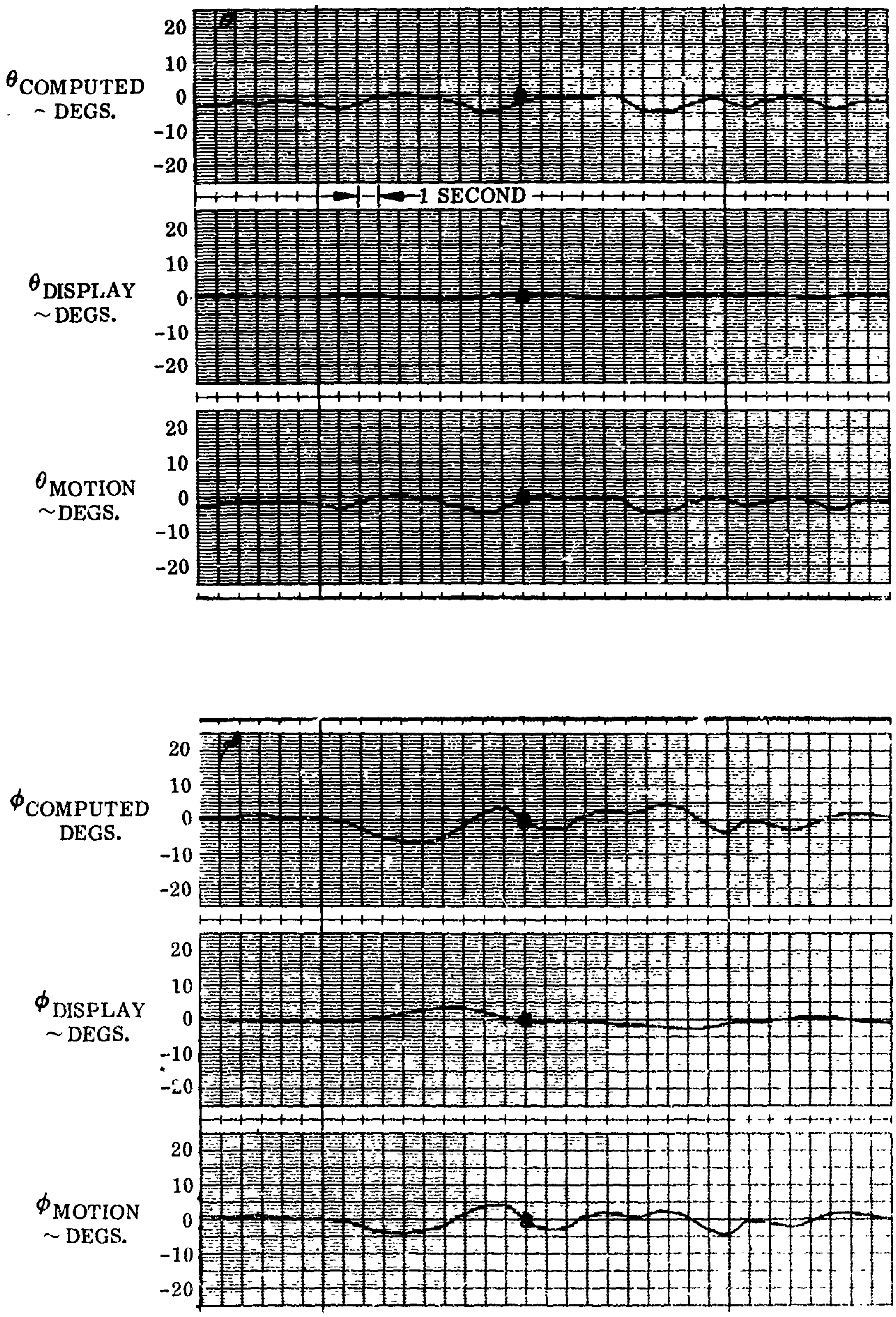


FIGURE 3. SAMPLE TIME HISTORY

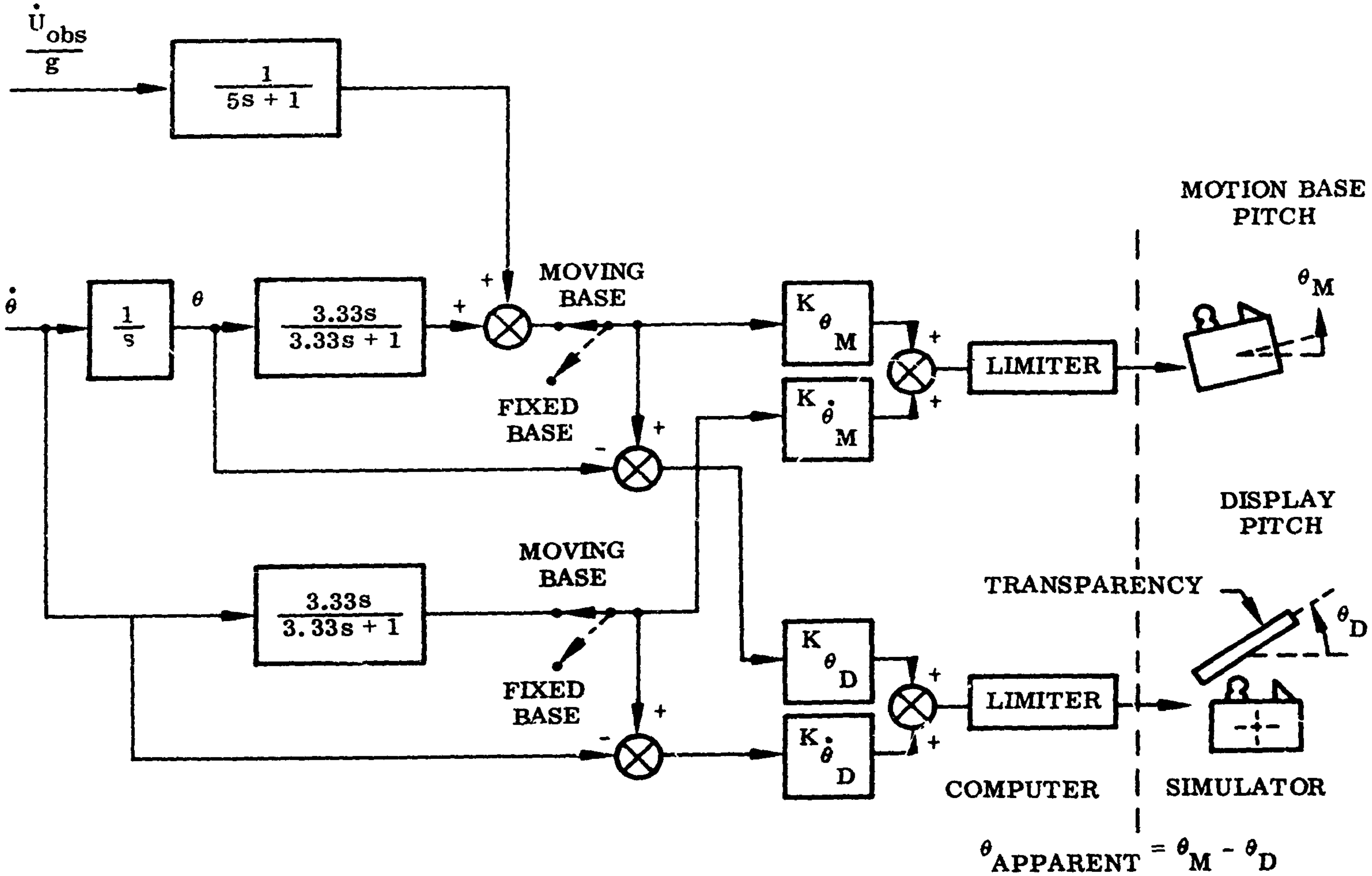


FIGURE 4. LONGITUDINAL MOTION SYSTEM

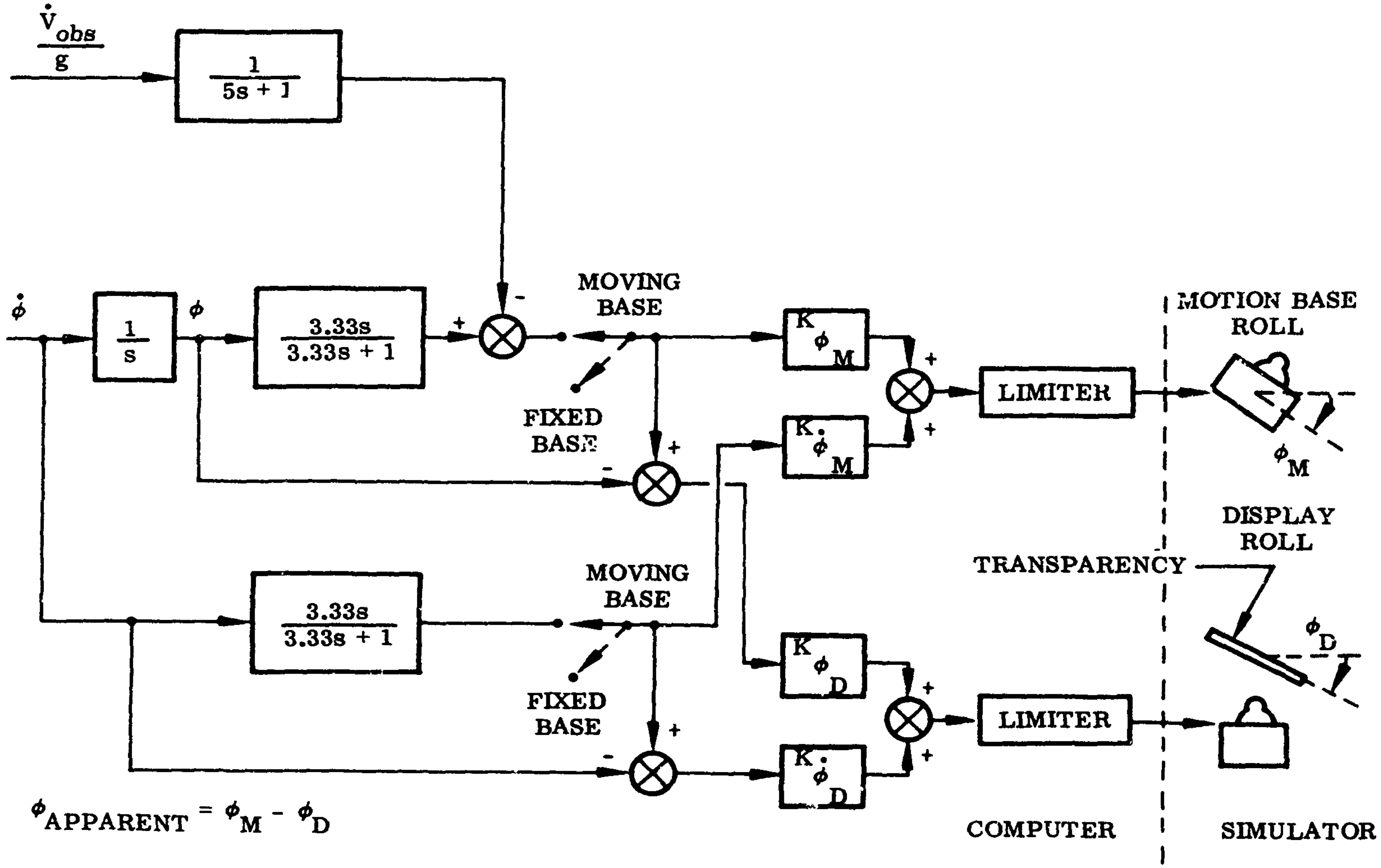


FIGURE 5. LATERAL MOTION SYSTEM

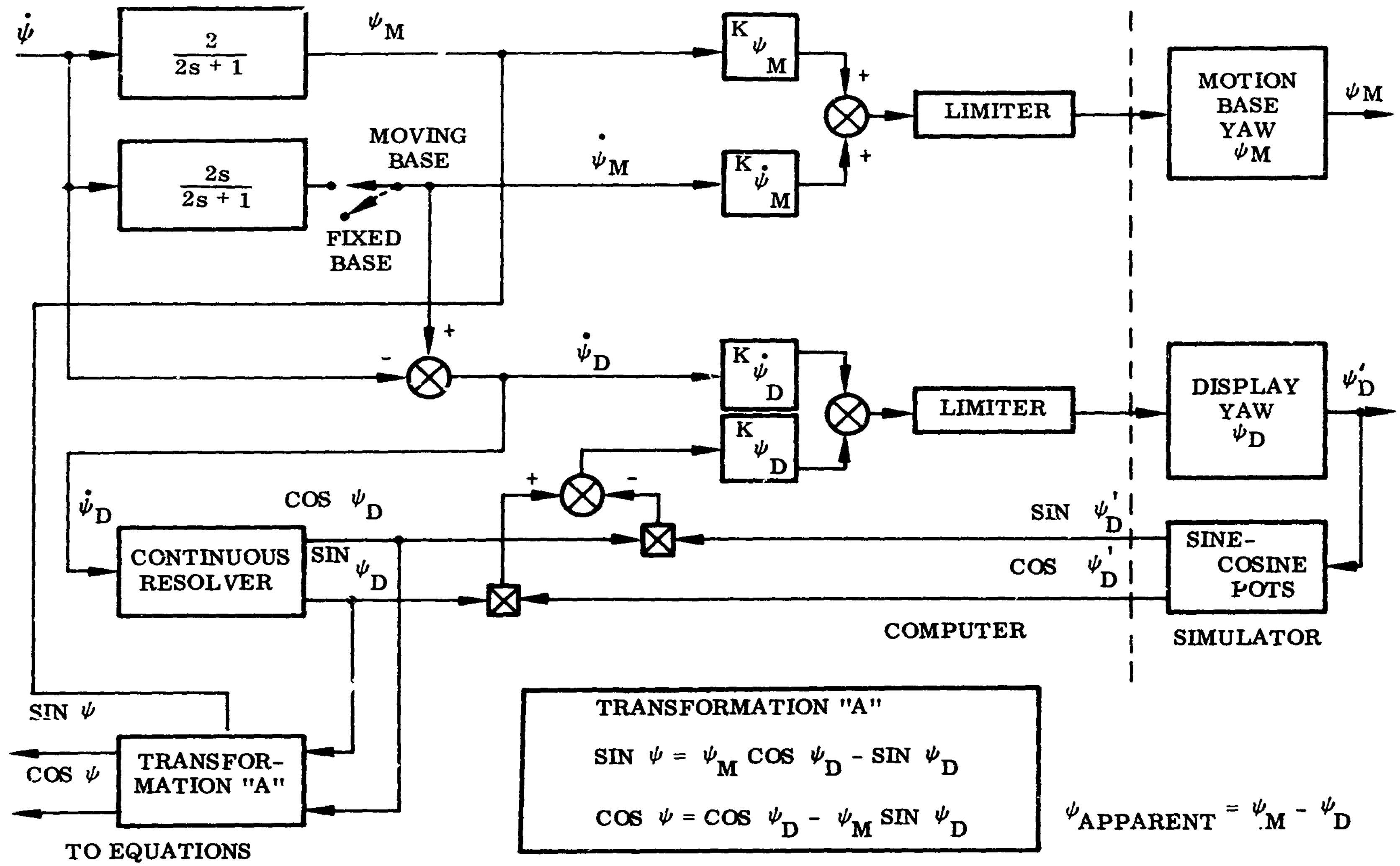


FIGURE 6. YAW MOTION SYSTEM

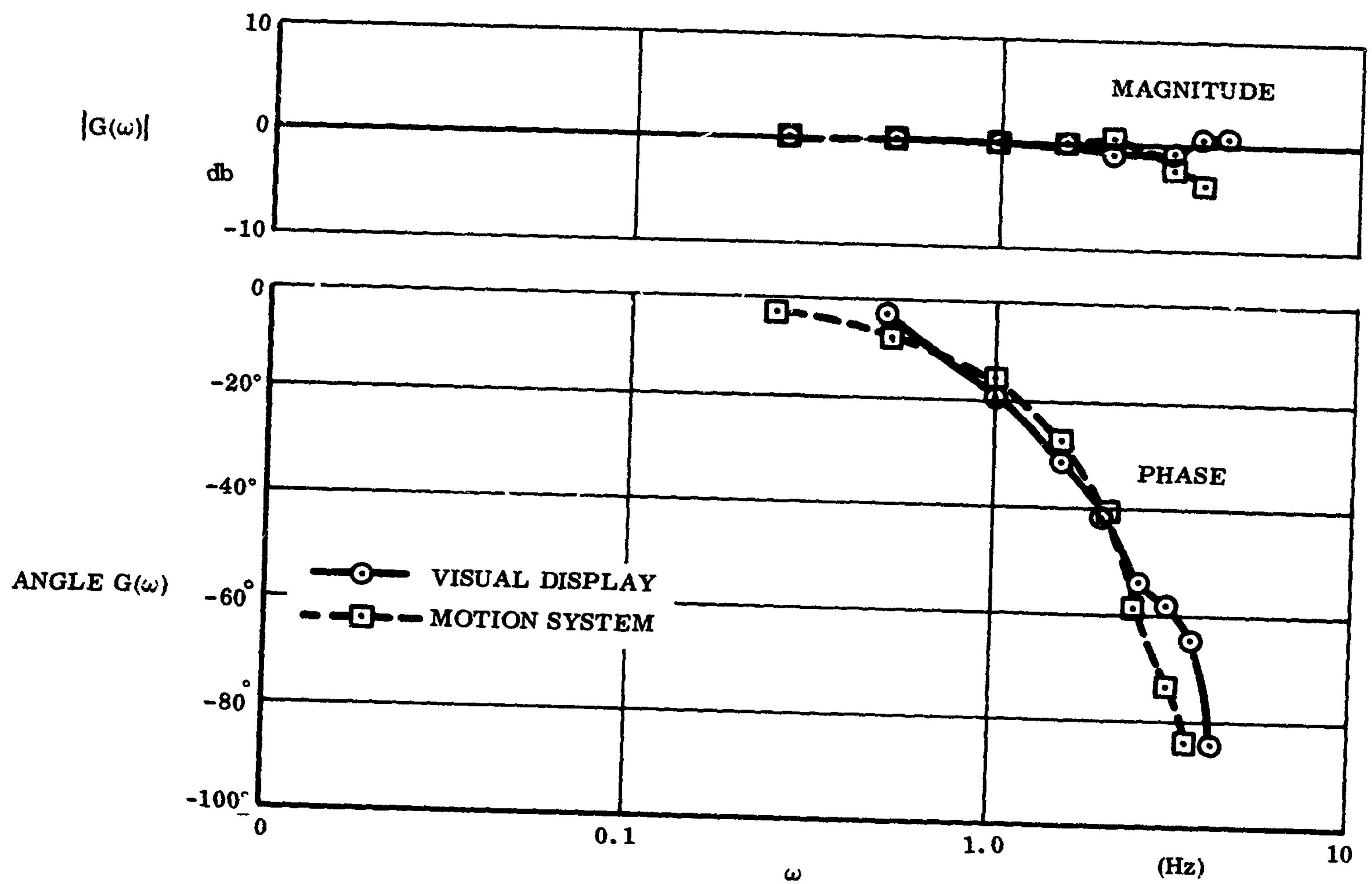


FIGURE 7. SIMULATOR FREQUENCY RESPONSE - PITCH

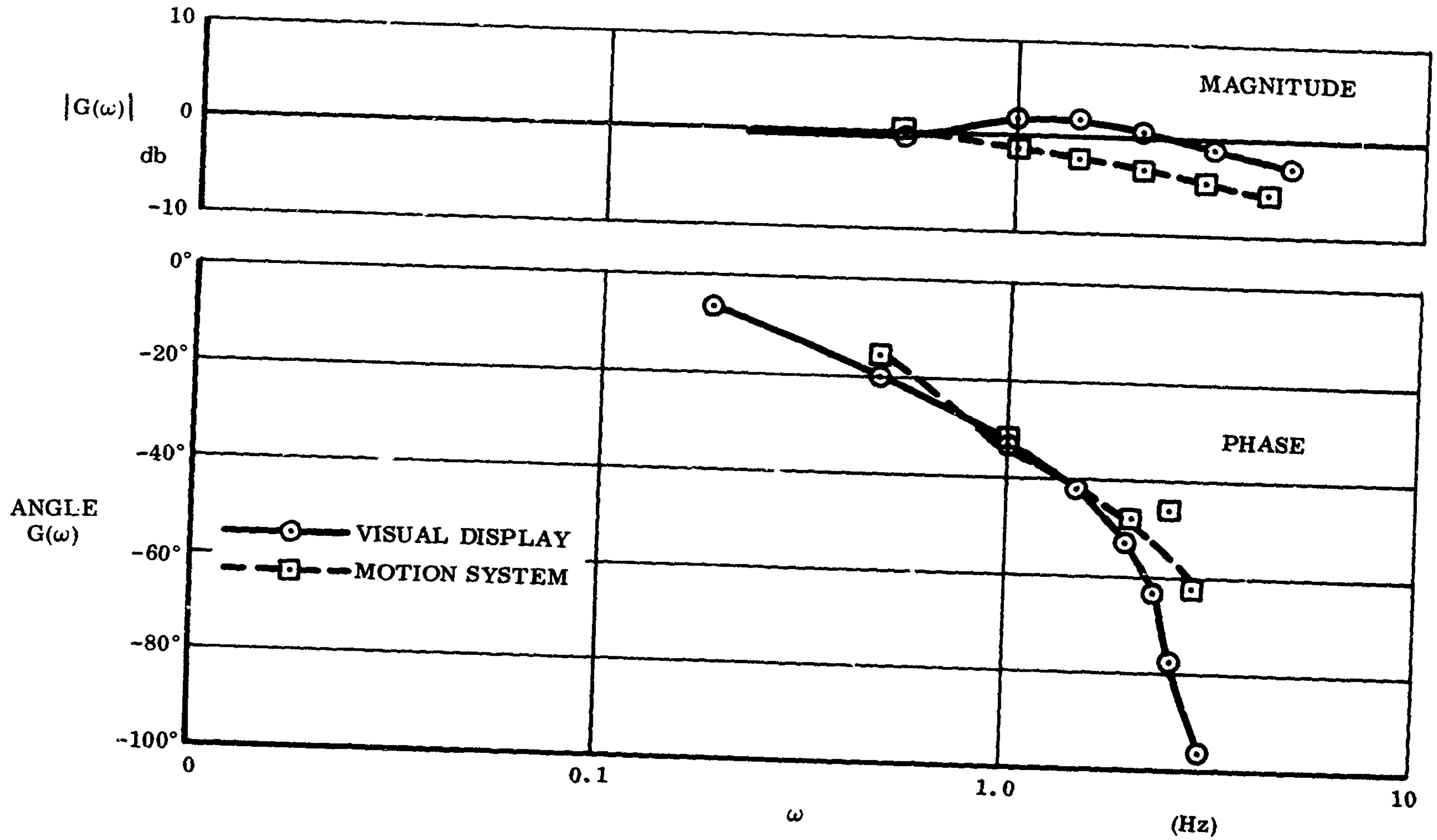


FIGURE 8. SIMULATOR FREQUENCY RESPONSE - ROLL

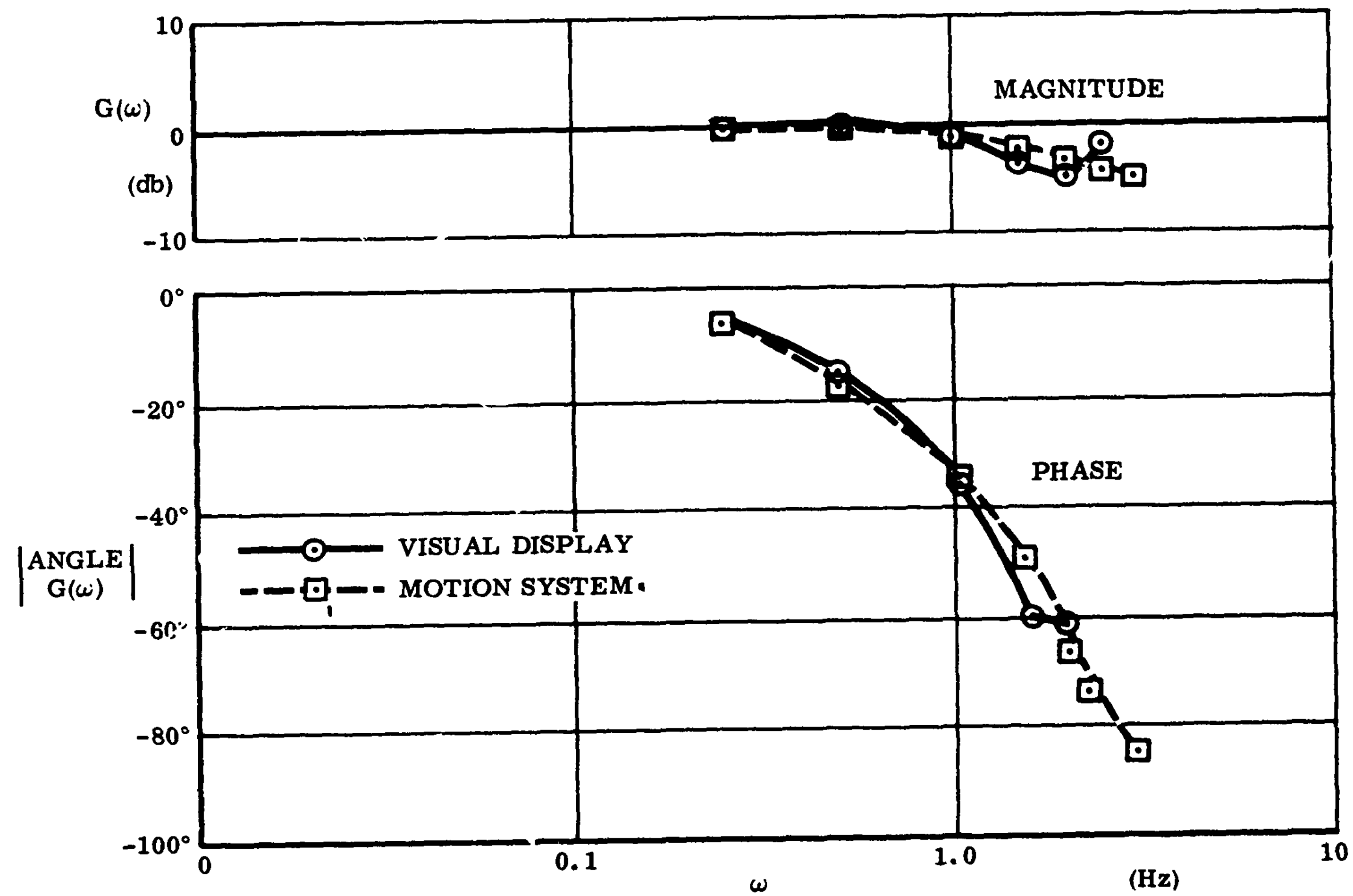


FIGURE 9. SIMULATOR FREQUENCY RESPONSE - YAW

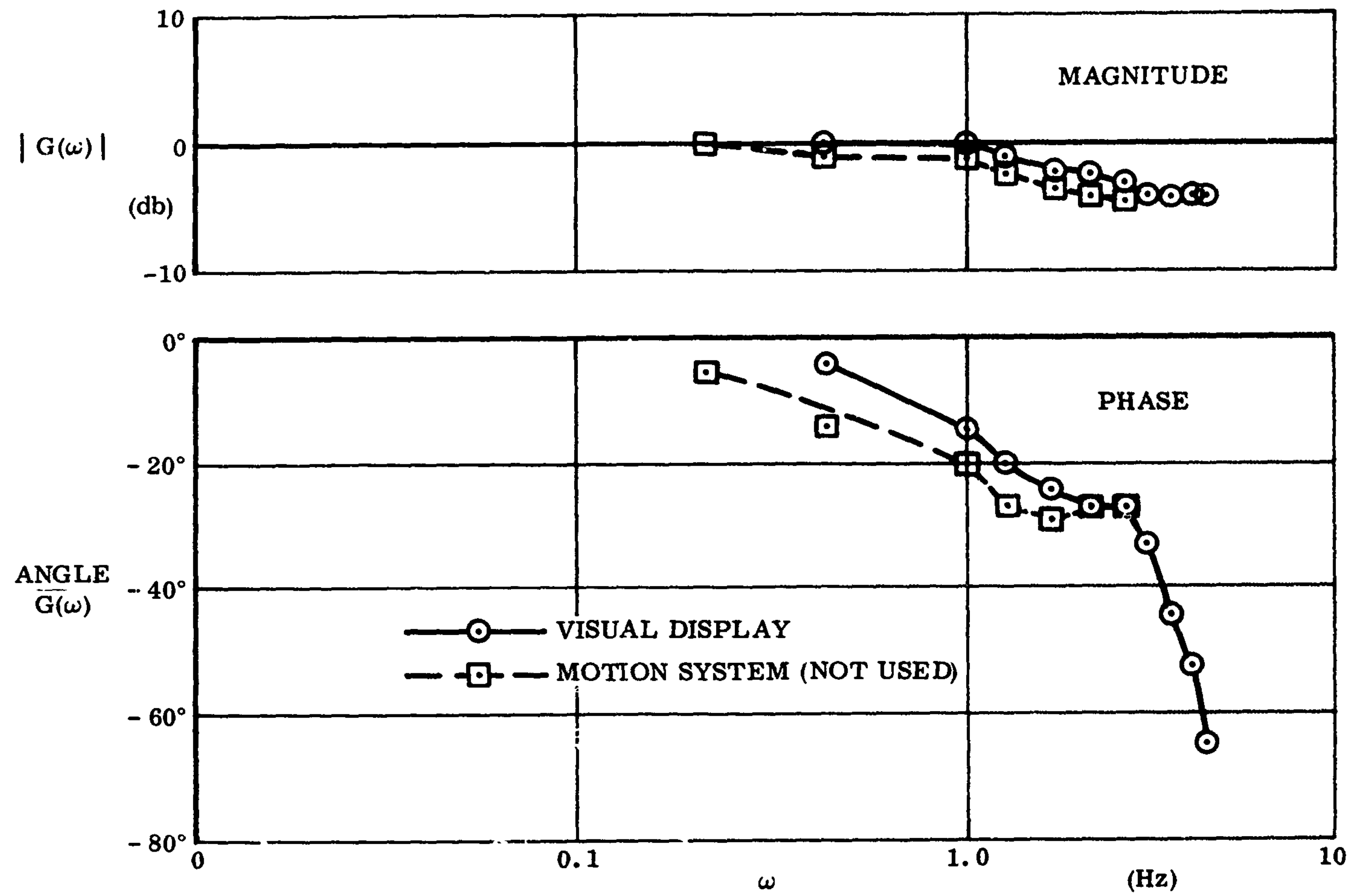


FIGURE 10. SIMULATOR FREQUENCY RESPONSE - VERTICAL

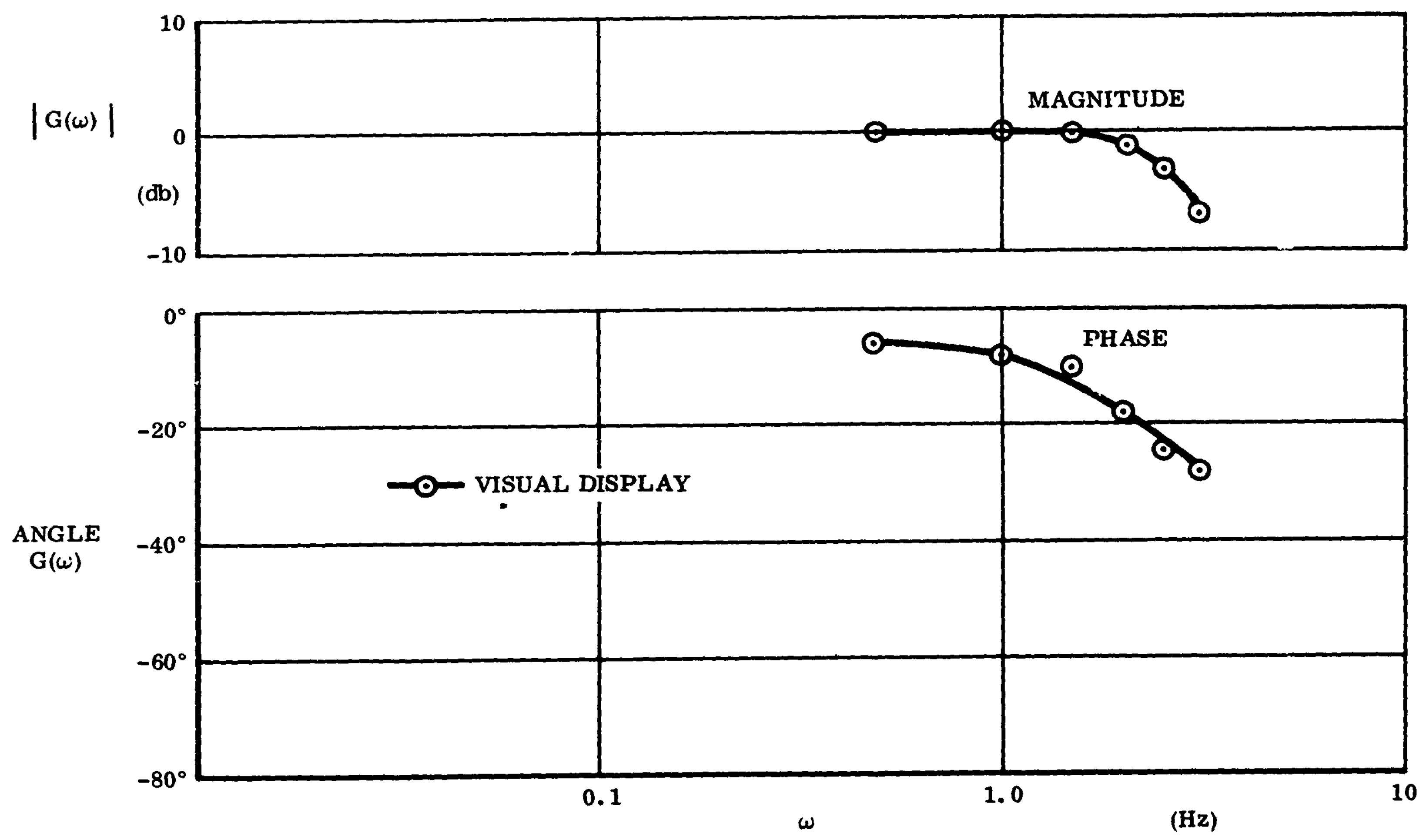


FIGURE 11. SIMULATOR FREQUENCY RESPONSE - LATERAL

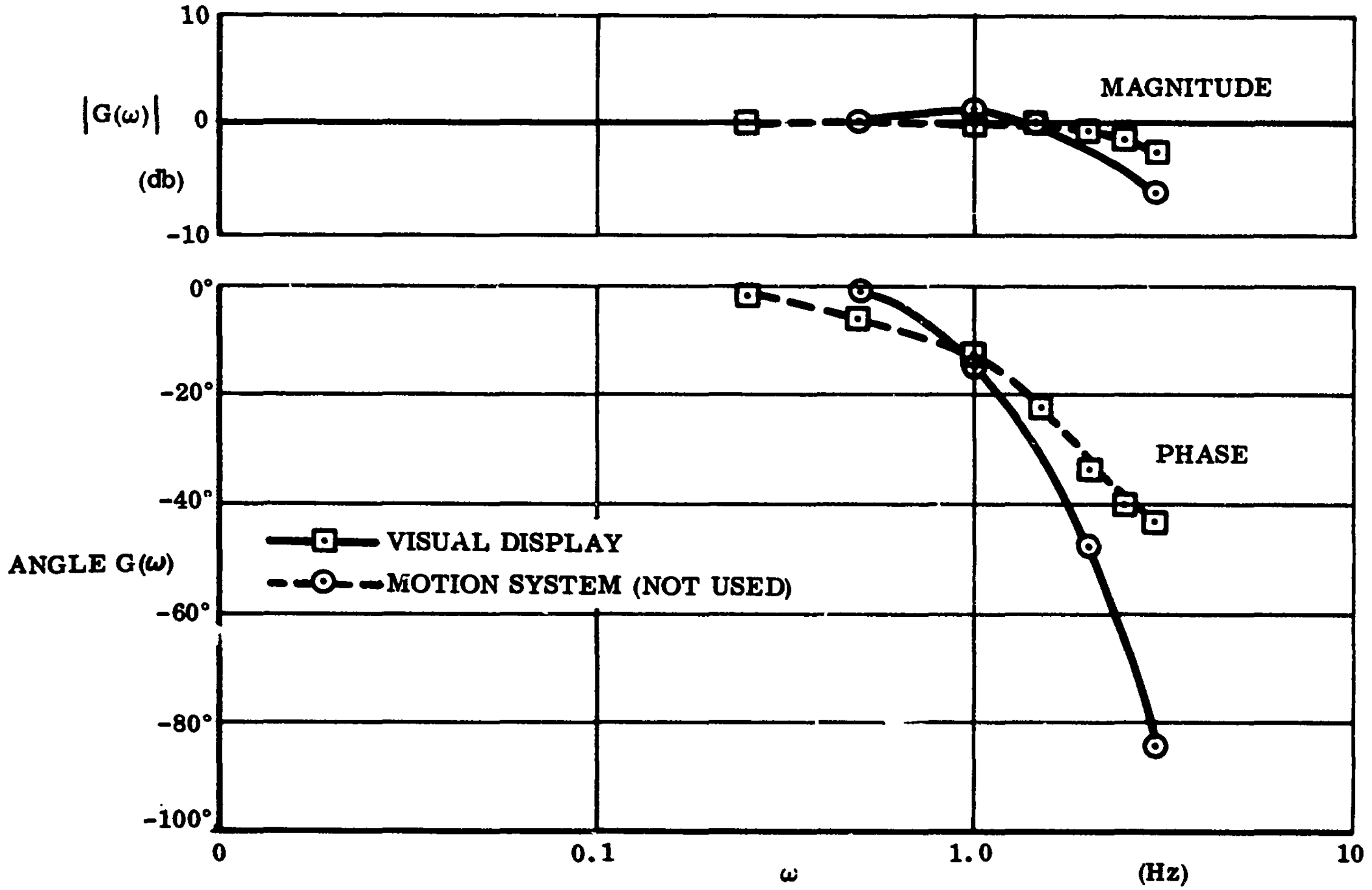


FIGURE 12. SIMULATOR FREQUENCY RESPONSE - FORWARD

SECTION III

EQUATIONS OF MOTION

The following vehicle equations of motion for six degrees of freedom were programmed on the analog computers:

$$\dot{u} = X_u u - g\cos\phi\sin\theta + rv - qw$$

$$\dot{v} = Y_v v + g\sin\phi + pw - ru$$

$$\dot{w} = Z_w w + g\cos\phi\cos\theta + qu - pv + Z_\delta \delta_c$$

$$\dot{p} = L_v v + L_p p + L_\phi \phi + L_\delta \delta_a$$

$$\dot{q} = M_u u + M_q q + M_\theta \theta + M_\delta \delta_e$$

$$\dot{r} = N_v v + N_r r + N_\delta \delta_r$$

Steady winds and turbulence were applied to the vehicle through the u and v terms of the above equations where:

$$u = \int \dot{u}\,dt + u_{gust} + W_x \cos\psi + W_y \sin\psi$$

and

$$v = \int \dot{v}\,dt + v_{gust} + W_y \cos\psi - W_x \sin\psi$$

The simulator gimbal system is constructed such that the order of rotation is not normally used in aircraft motion analyses. The order is pitch, roll, and yaw, starting from fixed structure to the transparency. The order used for the gimbal drives is the aforementioned order reversed (yaw, roll, and pitch) since this is the order as viewed from the transparency (ground) to the point light source (pilot's eye or aircraft). The angular rates are:

$$\dot{\psi} = r\sec\phi\cos\theta - p\sec\theta\sin\theta$$

$$\dot{\phi} = p\cos\theta + r\sin\theta$$

$$\dot{\theta} = q - r\tan\phi\cos\theta + p\tan\phi\sin\theta$$

For purposes of analog mechanization for a VTOL aircraft, it appears valid to simplify the angular rate equations to:

$$\dot{\psi} = r - p \sin\theta$$

$$\dot{\phi} = p + r \sin\theta$$

$$\dot{\theta} = q - r \sin\phi$$

The pilot station accelerations are:

$$\dot{U} = \dot{u} - rv + qw = X_u u - g \cos\phi \sin\theta$$

$$\dot{V} = \dot{v} - pw + ru = Y_v v + g \sin\phi$$

$$\dot{W} = \dot{w} - qu + pv = Z_w w + g \cos\phi \cos\theta + Z_\delta \delta_c$$

At the pilot station, the observed accelerations are:

$$\dot{U}_{obs} = \dot{U} + g \cos\phi \sin\theta = X_u u$$

$$\dot{V}_{obs} = \dot{V} - g \sin\phi = Y_v v$$

The cockpit velocities in the earth axes for transparency translational drives are:

$$\dot{X} = U \cos\psi - V \sin\psi + W (\sin\theta \cos\psi + \sin\phi \sin\psi)$$

$$\dot{Y} = U \sin\psi + V \cos\psi + W (\sin\theta \sin\psi - \sin\phi \cos\psi)$$

$$\dot{Z} = -U \cos\phi \sin\theta + V \sin\phi + W \cos\phi \cos\theta$$

Turbulence was simulated by passing the output of a white-noise generator through a first-order filter having a break frequency at 0.314 rad/sec:

$$\frac{U_{gust}}{N_g} = \frac{K_{u_{gust}}}{s + 0.314}$$

$$\frac{V_{gust}}{N_g} = \frac{K_{v_{gust}}}{s + 0.314}$$

where $K_{u_{gust}}$ and $K_{v_{gust}}$ were adjusted to yield the desired rms values of the turbulence, and the N_g is the output of the white-noise generator.

SECTION IV

DESCRIPTION OF TASKS

The simulation was intended to provide experimental data for establishing longitudinal and lateral-directional handling qualities specifications for VTOL aircraft in the hover and low-speed maneuvering range.

For the purpose of the simulation, it was assumed that the thrust vector was tied to the body axis; i.e., it was always oriented along the z-body axis. Since no thrust-vectoring control was assumed, body attitude changes were required to produce the necessary horizontal component of thrust to maneuver and to hold ground position in winds.

The longitudinal and lateral modes were the basic areas of interest under investigation. Therefore, the dynamics of the height mode were intended to be "good" and to present no primary control problems. However, it was considered realistic to have the pilot control height with collective while using cyclic in order to give him the additional workload required in the real task. Although the height degree of freedom was not aerodynamically coupled with the longitudinal and lateral-directional modes, height changes occurred when the thrust vector was tilted in various ways for horizontal position changes.

When considering the possible uses of a VTOL vehicle in the low-speed maneuvering and hover range, it was considered that one of the most demanding tasks was the low-altitude hover required just prior to a vertical landing. Even if the vehicle spends most of its mission time in some other part of the flight envelope, if it is in fact a true VTOL, the entire flight is climaxed when a vertical landing is safely performed by the pilot. In addition to this requirement by all VTOLs, some VTOLs may be used for pilot rescue where accurate hovering capability is also a necessity. With the exception of helicopters, most classes of VTOL aircraft probably will have fairly high disc loadings; therefore, ground effects and reingestion prevent stable hover conditions close to the ground. In order to obtain data which are as similar to the operational use as possible, a hover altitude of 30 feet was specified with a maximum variation of ±5 feet. This is probably a minimum altitude acceptable with respect to reingestion and ground effects for some vehicles; however, this altitude was selected to increase the pilot's visual cue sensitivity.

In this simulation, the vertical descent to touchdown was not considered because the control problems in this regime vary with the specific type of VTOL aircraft. Since the simulation did not include ground effects, the evaluation was based only on what the pilot observed at this specified hover altitude and above.

In order to permit the pilot the opportunity to maneuver the vehicle in such ways as are considered to be typical of operational use, the following tasks were evaluated:

1. Vertical liftoff to hover at 30 feet at the starting point of the ground-referenced square pattern. The square was 80 feet on a side, marked by lines approximately 6 inches wide. (Refer to Figure 13.)

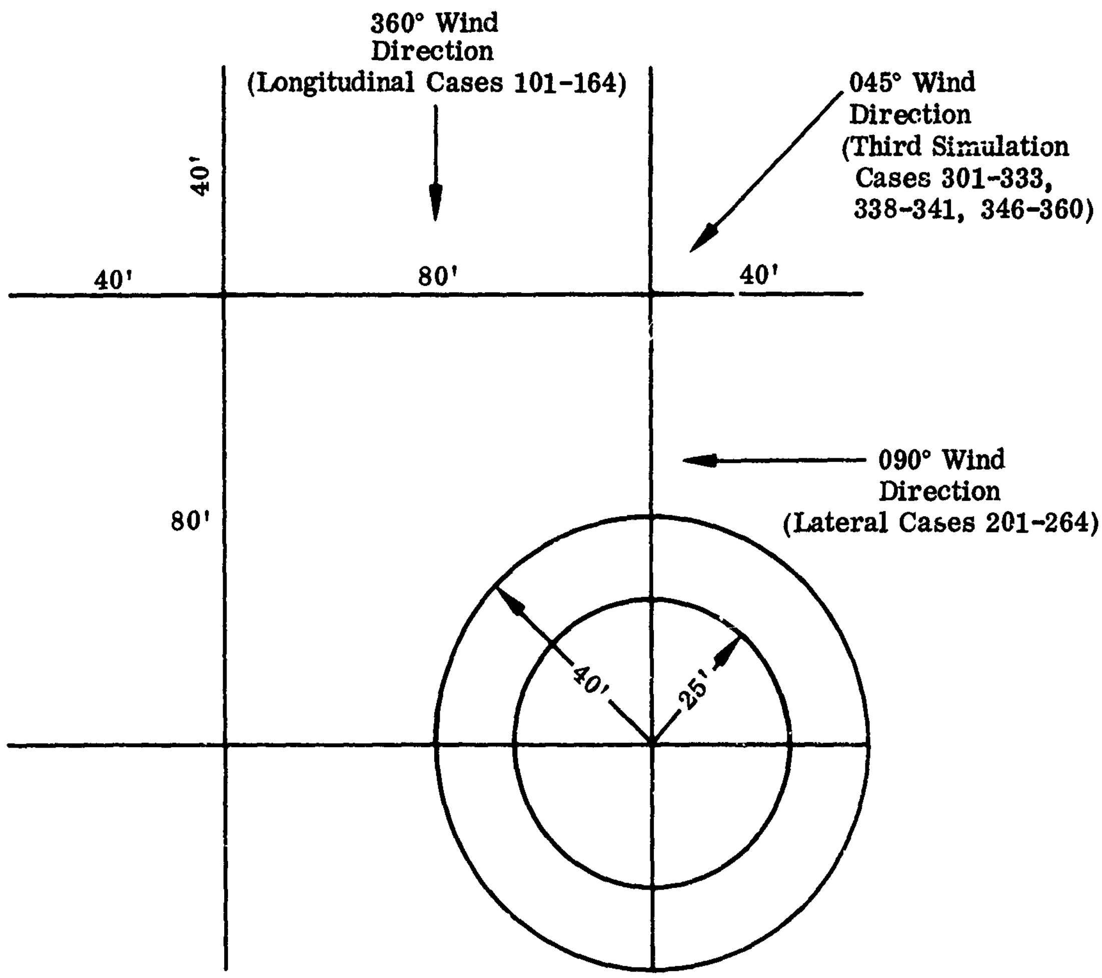


FIGURE 13. GROUND-REFERENCED SQUARE PATTERN

2. Maintaining 30-foot altitude, the square was traced out holding constant heading within ±5 degrees. This required forward, sideward, rearward, and sideward (other direction) flight in that order. The pilot attempted to maneuver the vehicle to trace out the ground path within ±5 feet of the pattern outline, with ground speed equivalent to a slow walk. The pilot hovered momentarily at each corner.

3. While hovering over the starting point of the square at an altitude of 30 feet, a series of 90-degree turns was made over a spot, establishing hover after each 90-degree turn. A 25-foot and a 40-foot-radius circle were available on the ground for reference in performing these turns and holding the hovers.

4. At an altitude of 30 feet, crosswind approaches (from both directions) were performed; each approach was followed by a 90-degree turn into the wind over the proposed touchdown spot. The pilot attempted to stabilize hover as quickly as possible after turning into the wind over the spot, assuming a vertical descent to touchdown would be subsequently performed. The maximum position variations considered acceptable during this hover were ±5 feet longitudinally and ±3 feet laterally.

5. In addition to the above maneuvers, it was also of interest to investigate the pilot control problems involved when performing a quick-stop maneuver. The purpose of the quick stop was to bring the vehicle to zero ground speed in the minimum time. In the first and second simulation, a forward quick stop was performed for the longitudinal evaluations and a sideways quick stop for the lateral evaluations. These were performed into the wind. In the third simulation, both forward quick stops (into the wind) and sideways quick stops (upwind and downwind) were performed.

A steady wind with gusts was simulated in most of the cases evaluated to make the hover and low-speed maneuvering realistic. (A few cases in the third simulation were evaluated without winds or turbulence.) Turbulence alone, without being superimposed on a steady wind, does not define the complete control problem when a maneuver is tied to a ground reference. In a strong wind with gusts, turn-over-a-spot becomes one of the most difficult maneuvers to perform because of changing requirements in all three pilot controls (cyclic, collective, and rudder) as the heading of the vehicle changes with respect to the wind direction.

In the first and second simulations, a steady wind from 360 degrees was simulated for the longitudinal evaluations and from 090 degrees for the lateral evaluations. In the third simulation, the wind was from 045 degrees. (Refer to Figure 13) The winds were of 10-knot magnitude and were fixed to earth axes. The turbulence was fixed to the aircraft body axes and was two knots rms (3.4 fps) in both the longitudinal and lateral axes.

Before performing the above maneuvers for record, the pilot executed a practice run during which various levels of control sensitivity were investigated. During the first and second simulations, selection of control sensitivity for the axis under evaluation was by means of a single knob mounted in the simulator cockpit. The knob was marked only with an indexing line so that it could be reset to the same value after every run. The value of sensitivity selected by the pilot was read from an amplifier in the analog computer. Hence, the pilot did not know the value he had selected. After adjusting the knob to what he considered an optimum selection, the pilot flew the prescribed task with this selection. For the third simulation, some of the configurations had fixed control sensitivities. For the others, both the pitch control and the roll control sensitivities were adjusted to values that the pilot considered optimum. These values then were fixed and, based on the selected values, the configuration was evaluated. There were two knobs in the cockpit for adjusting control sensitivities: one adjusted both the pitch and roll sensitivities simultaneously and equally, and the other could be used to incrementally adjust roll sensitivity if desired.

Immediately following each record run, the pilot gave oral comments into a tape recorder. The pilot comment cards used as guides for these comments are provided in Figure 14(A) and 14(B). Pilot comments are presented in detail in Appendix II. A pilot rating (PR) was also given for each configuration using the Revised Pilot Rating Scale (CAL Report No. 153). This scale is reproduced in Figure 15.

I. Make general comments as desired.

II. Initial impressions and selection of control sensitivity.

III. Specific comments (be prepared to comment on objectionable and favorable features below).

A. Air-taxi-around-the-square.

1. Cyclic control.
   (a) Ability to initiate motion (each direction).
   (b) Ability to stabilize and hold preselected rate of movement.
   (c) Ability to stop precisely and come to hover at corners.
   (d) Are excessive attitude changes (pitch and roll) required?
   (e) Ability to remain within ground track limits.
   (f) Control feel.
2. Rudder control.
   (a) Response.
   (b) Sensitivity.
   (c) Ability to hold heading.

B. Turn-over-a-spot.

1. Cyclic control.
   (a) Ability to remain over spot.
   (b) Attitude control (pitch and roll).
2. Rudder control.
   (a) Ability to initiate turn rate.
   (b) Ability to stabilize and hold preselected turn rate.
   (c) Ability to stop on preselected heading.

C. Precision Hover.

1. Ability to establish and maintain precision hover.
   (a) Attitude and angular rates.
   (b) Position.
2. Adequate for vertical landing?
3. Control activity.

D. Quick stops.

1. Can you stop as quickly as you would like to?
2. Are excessive attitude changes required?
3. Ability to hold heading and altitude.
4. Control motions required.

E. 90-degree crosswind turns.

1. Is time to accomplish maneuver excessive?
2. Overshoot-undershoot tendencies.
3. Ability to establish heading and position over spot.
4. Control activity - adequacy of control power.

F. Did height control requirement make maneuvers more difficult?

G. Secondary dynamics.

1. Did lateral-directional and height dynamics affect your evaluation of longitudinal dynamics?
2. Did longitudinal and height dynamics affect your evaluation of lateral-directional dynamics?

IV. Overall Evaluation.

1. Objectionable features.
2. Favorable features.
3. Special piloting techniques.
4. Pilot rating; why?

IMPORTANT: PLEASE AVOID ALL REFERENCE AND COMPARISONS TO ANY OTHER FLIGHT. MAKE EACH SET OF COMMENTS INDEPENDENT OF ANY OTHER.

FIGURE 14(A). PILOT COMMENT CARD FOR FIRST AND SECOND SIMULATION

I. General comments as desired.

II. Comments on selection of control sensitivities.

III. Specific comments (be prepared to comment on objectionable and favorable features below).

A. Air-taxi-around-the-square.

1. Ability to initiate motion (each direction).
2. Ability to stabilize and hold preselected rate of movement.
3. Ability to stop precisely and come to hover at corners.
4. Are excessive attitude changes (pitch and roll) required?
5. Ability to remain within ground-track limits.
6. Control feel, forces, deflections, trim.
7. Response to control inputs (all axes).
8. Sensitivities.
9. Ability to hold heading.

B. Turn-over-a-spot.

1. Ability to remain over spot.
2. Attitude control (pitch and roll).
3. Ability to initiate turn rate.
4. Ability to stabilize and hold preselected turn rate.
5. Ability to stop on preselected heading.

C. 90-degree crosswind turns.

1. Is time to accomplish maneuver excessive?
2. Overshoot or undershoot tendencies.
3. Ability to establish heading and position over spot.
4. Control activity and adequacy of control power.

D. Precision hover.

1. Ability to establish and maintain precision hover.

(a) Attitude and angular rates.
(b) Position.

2. Adequate for vertical landing?
3. Control activity.

E. Quick stops.

1. Can you stop as quickly as you would like?
2. Are excessive attitude changes required?
3. Ability to hold heading and altitude.
4. Control motions required.

F. Secondary dynamics.

1. Did directional and height dynamics affect your evaluation?

IV. Overall evaluation.

A. Objectionable features.

B. Favorable features.

C. Special piloting techniques.

D. Pilot rating; why?

IMPORTANT: PLEASE AVOID ALL REFERENCE AND COMPARISONS TO ANY OTHER FLIGHT. MAKE EACH SET OF COMMENTS INDEPENDENT OF ANY OTHER.

FIGURE 14(B). PILOT COMMENT CARD FOR THIRD SIMULATION

CONTROLLABLE CAPABLE OF BEING CONTROLLED OR MANAGED IN CONTEXT OF MISSION, WITH AVAILABLE PILOT ATTENTION	ACCEPTABLE MAY HAVE DEFICIENCIES WHICH WARRANT IMPROVEMENT, BUT ADEQUATE FOR MISSION. PILOT COMPENSATION, IF REQUIRED TO ACHIEVE ACCEPTABLE PERFORMANCE, IS FEASIBLE.	SATISFACTORY MEETS ALL REQUIREMENTS AND EXPECTATIONS, GOOD ENOUGH WITHOUT IMPROVEMENT CLEARLY ADEQUATE FOR MISSION.	EXCELLENT, HIGHLY DESIRABLE	A1
			GOOD, PLEASANT, WELL BEHAVED	A2
			FAIR. SOME MILDLY UNPLEASANT CHARACTERISTICS. GOOD ENOUGH FOR MISSION WITHOUT IMPROVEMENT.	A3
		UNSATISFACTORY RELUCTANTLY ACCEPTABLE. DEFICIENCIES WHICH WARRANT IMPROVEMENT. PERFORMANCE ADEQUATE FOR MISSION WITH FEASIBLE PILOT COMPENSATION.	SOME MINOR BUT ANNOYING DEFICIENCIES. IMPROVEMENT IS REQUESTED. EFFECT ON PERFORMANCE IS EASILY COMPENSATED FOR BY PILOT.	A4
			MODERATELY OBJECTIONABLE DEFICIENCIES. IMPROVEMENT IS NEEDED. REASONABLE PERFORMANCE REQUIRES CONSIDERABLE PILOT COMPENSATION.	A5
			VERY OBJECTIONABLE DEFICIENCIES. MAJOR IMPROVEMENTS ARE NEEDED. REQUIRES BEST AVAILABLE PILOT COMPENSATION TO ACHIEVE ACCEPTABLE PERFORMANCE.	A6
	UNACCEPTABLE DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT. INADEQUATE PERFORMANCE FOR MISSION EVEN WITH MAXIMUM FEASIBLE PILOT COMPENSATION.		MAJOR DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT FOR ACCEPTANCE. CONTROLLABLE. PERFORMANCE INADEQUATE FOR MISSION, OR PILOT COMPENSATION REQUIRED FOR MINIMUM ACCEPTABLE PERFORMANCE IN MISSION IS TOO HIGH.	U7
			CONTROLLABLE WITH DIFFICULTY. REQUIRES SUBSTANTIAL PILOT SKILL AND ATTENTION TO RETAIN CONTROL AND CONTINUE MISSION.	U8
			MARGINALLY CONTROLLABLE IN MISSION. REQUIRES MAXIMUM AVAILABLE PILOT SKILL AND ATTENTION TO RETAIN CONTROL.	U9
UNCONTROLLABLE CONTROL WILL BE LOST DURING SOME PORTION OF MISSION.			UNCONTROLLABLE IN MISSION.	10

FIGURE 15. REVISED PILOT RATING SCALE

SECTION V

CONFIGURATIONS

FIRST SIMULATION

The primary purpose of the initial Norair experimental program was to obtain pilot rating data to help define the nature of a boundary presumed to lie in a particular region of the s-plane. This region of the s-plane was investigated because pilot model analyses indicated that it was situated between a region considered satisfactory for rate system oscillatory root locations and a region considered satisfactory for attitude system oscillatory root locations. This region is indicated in Figure 16.

The derivatives X_u and $M_u g$ were considered as defining a basic family of longitudinal configurations. This consideration was based on the assumption that at low speeds most vehicles have essentially no natural rate and attitude derivatives. The derivatives M_q and M_θ are created entirely by SAS and thus are considered as defining that SAS configuration rather than the basic airframe (see Figure 17).

The four basic X_u, $M_u g$ families selected for the experiment are defined by two values of X_u and two values of $M_u g$. The low value of X_u was chosen as representative of minimum X_u's that might occur on actual vehicles. A zero value of X_u was not considered realistic. The high value of X_u was selected as the maximum likely to occur in practice. Also, simulation studies at United Aircraft Research Laboratories indicated X_u did not have a significant effect on the flying qualities until $|X_u| > 0.2$. Degradations in pilot rating were found by UARL for larger values of X_u because of large gust response effects on position control at precision hover. The UARL simulations did not include steady winds.

The two values of $M_u g$ were selected to provide families having a high and low pitch gust sensitivity.

The s-plane location of the characteristic roots for a typical X_u, $M_u g$ family is shown in Figure 18. Figure 19 shows the values of X_u and $M_u g$ defining the four families along with the ranges of M_q and M_θ. The lateral-directional dynamics were held constant at a good value during the longitudinal evaluations.

Table I contains the values of the stability derivatives for Cases 1 through 58 which were examined during the first simulation. Also listed are the terms in the airframe cubic, $(s+\lambda)(s^2 + 2\zeta\omega_n s + \omega_n s + \omega_n^2)$, for the axis under evaluation.

All of these cases were evaluated both as longitudinal and as lateral configurations. In Section VI of this report, Cases 101 through 158 are longitudinal configurations, and 201 through 258 are lateral configurations. (These case numbers correspond to case numbers 1 through 58 in Table I).

The lateral, directional, and height derivatives used during the longitudinal evaluations are:

$N_v = 0.002$	$Z_\delta = -3.2$	$Y_v = -0.1$
$N_r = -1.0$	$L_p = -5.0$	$L_\phi = 0$
$N_\delta = 0.2$	$L_v g = -0.164$	
$Z_w = -1.0$	$L_\delta = 0.6$	

During the lateral evaluations, the following longitudinal, directional, and height derivatives were used:

$N_v = 0.0002$	$Z_\delta = -3.2$	$X_u = -0.1$
$N_r = -1.0$	$M_q = -3.0$	$M_\theta = 0$
$N_\delta = 0.2$	$M_u g = 0.32$	
$Z_w = -1.0$	$M_\delta = 0.32$	

The lateral simulation was directly analogous to the longitudinal simulation. Numerical values for lateral parameters were determined by the following transformations:

$$M_u g \rightarrow -L_v g$$

$$X_u \rightarrow Y_v$$

$$M_q \rightarrow L_p$$

$$M_\theta \rightarrow L_\phi$$

The airframe cubic root locations are, of course, identical for both sets of configurations.

Section VI indicates which cases were evaluated by each pilot. Each pilot evaluated the cases assigned to him, both as a longitudinal and as a lateral configuration.

The evaluation tasks consisted of hovering and low-speed ground-oriented flight tracks in the presence of a steady wind of 10 knots with gusts having an rms of 3.4 ft/sec. In addition, quick stops were also performed. The pilot was allowed to choose a value of control sensitivity which he considered optimum for performing both the hovering and quick-stop maneuvers. These values are given in Section VI.

SECOND SIMULATION

The second simulation consisted of a number of repeat configurations and new configurations. The new cases are numbers 59 through 64 in Table I. The new configurations were evaluated both as longitudinal configurations (Case Nos. 159 through 164) and as lateral configurations (Case Nos. 259 through 264) as above. The stability derivatives for the axes not under evaluation were the same as in the first simulation. The control sensitivities were selected by the pilots and are listed in Section VI.

THIRD SIMULATION

The stability derivatives for the third simulation are given in Table II. Also listed are the terms in the airframe cubic. For Cases 301 through 320 and 334 through 360, the longitudinal and lateral dynamics were identical. In all of these cases the cubic has the form $(s + \lambda)(s^2 + 2\zeta\omega_n s + \omega_n^2)$, and the values listed for λ, ζ, and ω_n apply to both axes. For Cases 321 through 333, the cubic has the form $(s + \lambda_{\theta_1})(s + \lambda_{\theta_2})(s + \lambda_{\theta_3})$ for the longitudinal axis and $(s + \lambda_{\phi_1})(s + \lambda_{\phi_2})(s + \lambda_{\phi_3})$ for the lateral axis.

For Cases 301 through 345, the pilots selected values of control sensitivities in both pitch and roll. These values are given in Section VI. For Cases 346 through 360, the sensitivities were fixed and were the same for both pitch and roll. These values are given in Table II.

The directional and height derivatives were the same as for the first simulation.

Cases 301 - 320

For each configuration in this group the longitudinal and lateral dynamics were identical. The configurations were selected to provide an s-plane survey. Dynamics were varied in a specific way by changing the rate and attitude derivatives (M_q, M_θ, L_p, L_ϕ). Drag and speed stability parameters were held constant ($X_u = Y_v = -0.05$ and $L_v g = -M_u g = +0.33$). The twenty configurations which were selected are shown in Table II. Figure 20 illustrates the root locations. Steady winds, gusts, and feel and trim were present. Pilots selected their own control sensitivities.

Cases 321 - 333

The purpose of this group was to study the effects of unstable values of the speed stability parameters, $M_u g$ and $L_v g$. All other derivatives remained constant except the control sensitivities which were selected by the pilots. The group consisted of three distinct sets. In one set, both the pitch and roll axes had unstable values of the speed stability parameters. In the second set only the roll axis had instabilities. In the third set only the pitch axis had instabilities. Table II lists the derivatives. Steady winds, gusts, and feel and trim were present. Pilots selected control sensitivities.

Cases 334 - 345

Together, these three groups formed a subexperiment designed to obtain information on the effects of winds and cockpit control force characteristics on the ratings of configurations with high X_u, Y_v. The same four configurations were in each group. Longitudinal and lateral dynamics were identical and were selected from the first part of the simulation program. The following listing shows the experimental design and lists the configurations.

	FEEL AND TRIM PRESENT	NO FEEL AND TRIM
Steady Winds and Gusts	Cases 338 - 345	Cases 120 , 220 122 , 222 126 , 226 128 , 228
No Wind or Gusts	Cases 342 - 345	Cases 334 - 337

Cases 346 - 360

In this group, control sensitivities were primary experimental variables. Each pilot evaluated four different sensitivities for three sets of vehicle dynamics (the same as Cases 304, 309 and 314). For each configuration the longitudinal and lateral sensitivities as well as the longitudinal and lateral dynamics were identical. The vehicle dynamics differed only in natural frequency. Damping ratio was held constant at 0.7. Table II lists the parameters for this group. Steady winds, gusts, and feel and trim were present.

OSCILLATORY ROOT LOCATIONS

ATTITUDE SYSTEMS

		FEATURES
REGION (A)	- SATISFACTORY	$\zeta > 0.25$, $2 < \omega_n < 5$ 1/SEC
REGION (B)	- UNACCEPTABLE (diagonal hatching)	$\zeta < 0$
		$\omega_n > 0.8$ 1/SEC

RATE SYSTEMS

REGION (C)	- SATISFACTORY	$\zeta > 0$,	$\omega_n < 0.5$ 1/SEC
REGION (D)	- UNACCEPTABLE (cross-hatching)	$\zeta < -0.15$,	$\omega_n > 0.8$ 1/SEC

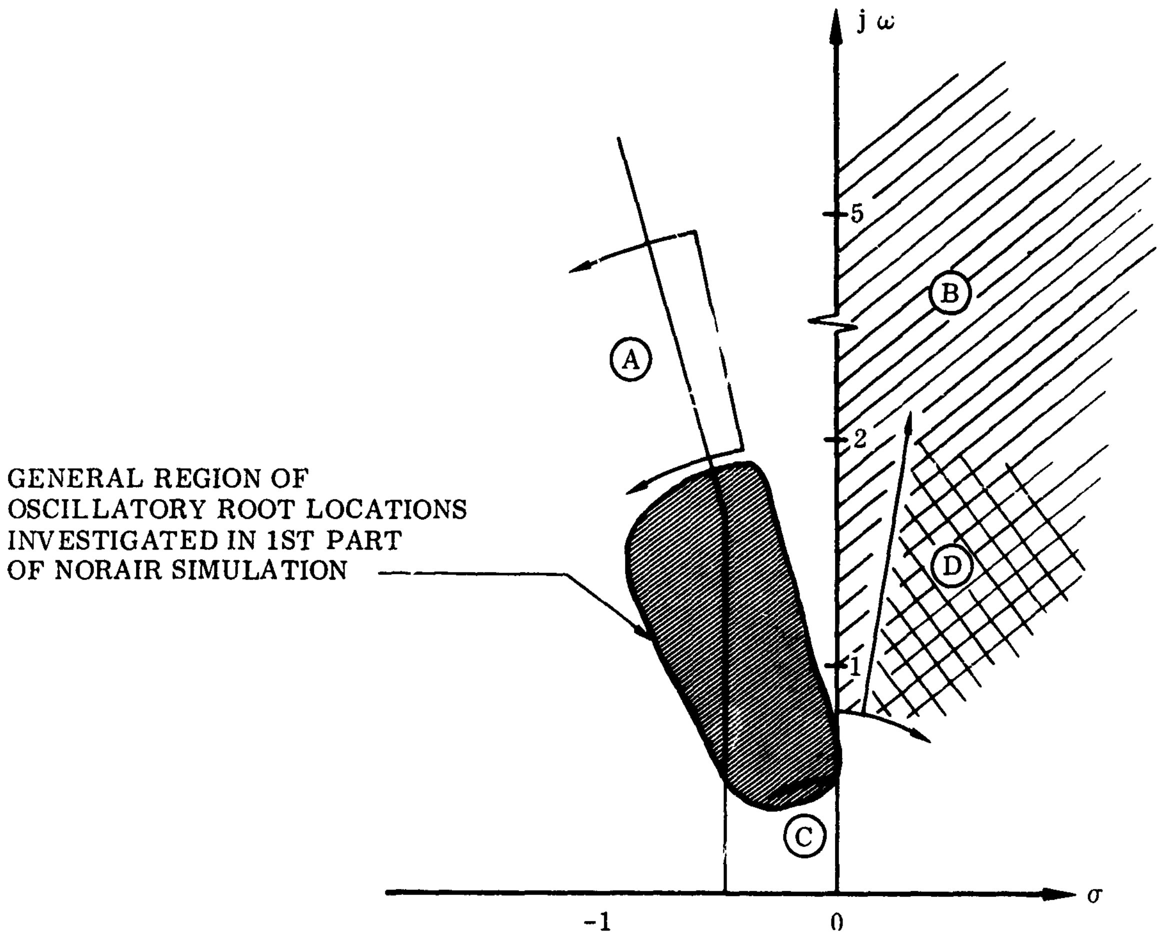
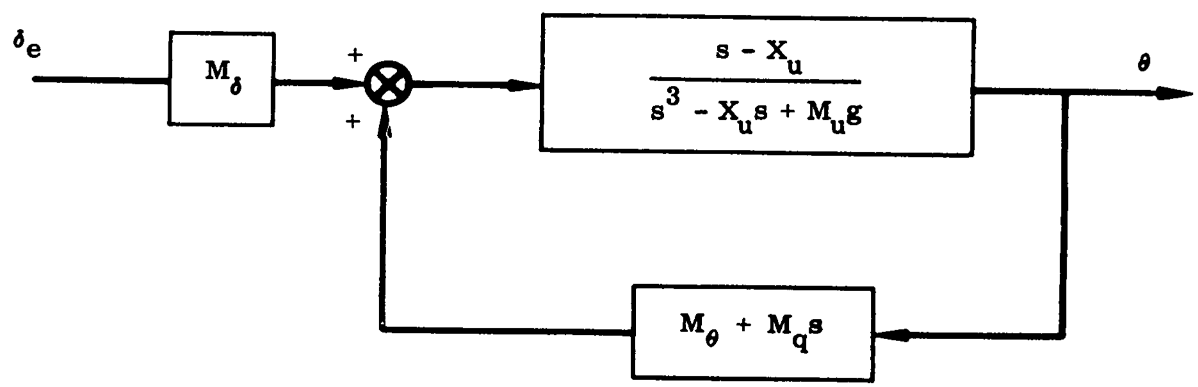


FIGURE 16. SUMMARY OF S-PLANE ROOT LOCATIONS

X_u AND $M_u g$ DEFINE BASIC AIRFRAME



M_θ AND M_q DEFINE SAS CONTROL LOOP

FIGURE 17. BASIC AIRFRAME WITH SAS CONTROL LOOP

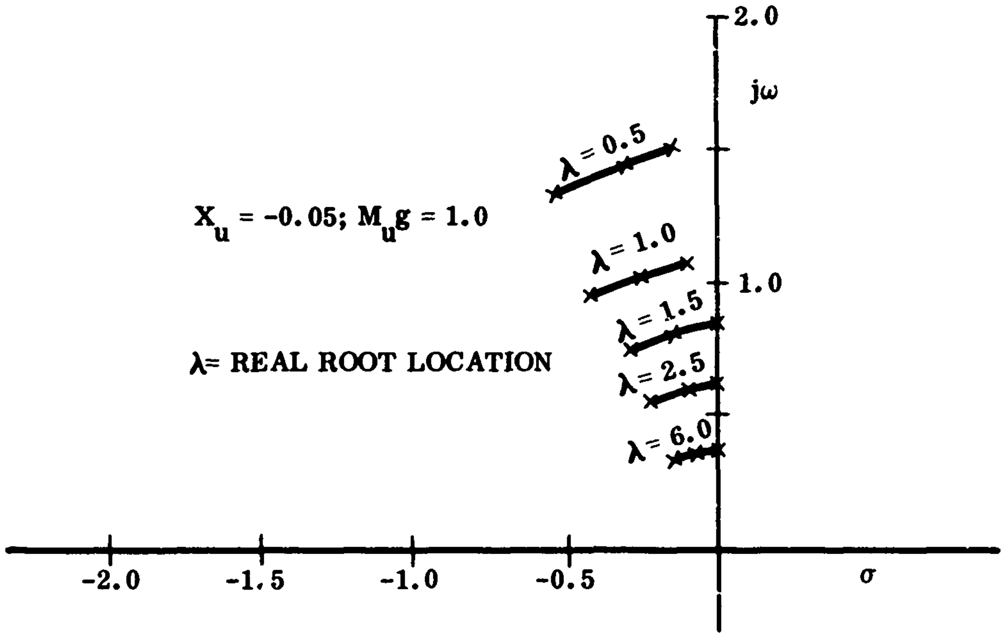


FIGURE 18. LOCATION OF CHARACTERISTIC ROOTS FOR A TYPICAL X_u, $M_u g$ FAMILY

FAMILY 1
$X_u = -0.05 \quad -6.15 \leq M_q \leq -0.30$
$M_u g = 1.0 \quad -2.80 \leq M_\theta \leq 0$

FAMILY 2
$X_u = -0.20 \quad -3.00 \leq M_q \leq -0.30$
$M_u g = 0.33 \quad -3.84 \leq M_\theta \leq 0$

FAMILY 3
$X_u = -0.20 \quad -6.30 \leq M_q \leq -0.30$
$M_u g = 1.00 \quad -3.98 \leq M_\theta \leq 0$

FAMILY 4
$X_u = -0.05 \quad -2.00 \leq M_q \leq 0$
$M_u g = 0.33 \quad -4.74 \leq M_\theta \leq 0$

X_u \ $M_u g$	LOW	HIGH
LOW	4	1
HIGH	2	3

FIGURE 19. VALUES OF X_u, $M_u g$ WITH RANGES OF M_q AND M_θ

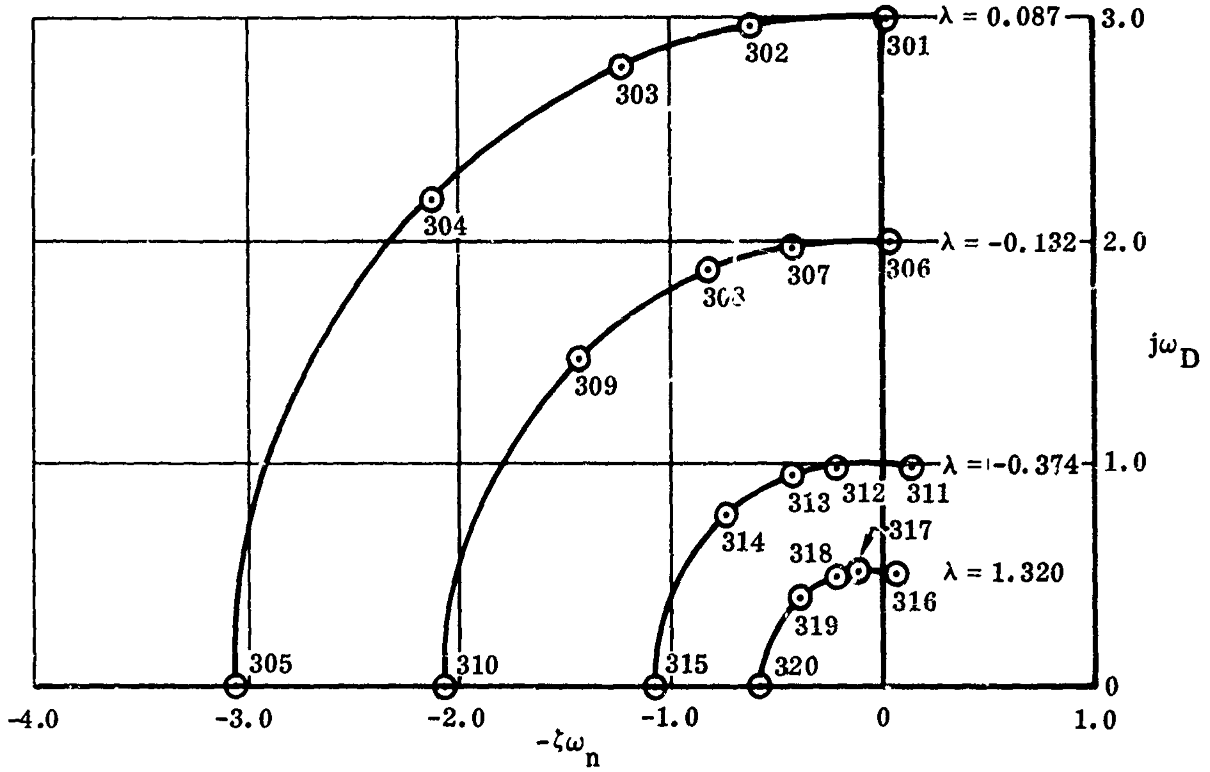


FIGURE 20. ROOT LOCATIONS FOR CASES 301 - 320

TABLE I. CONFIGURATIONS FOR FIRST AND SECOND SIMULATIONS

CASE NO	X_u	$M_u{}^g$	M_q	M_θ	λ	ζ	ω_n
1	-0.05	1.0	-1.65	-2.80	0.5	0.40	1.51
2			-1.05	-2.50	0.5	0.20	1.50
3			-0.65	-2.30	0.5	0.07	1.50
4			-1.95	-2.00	1.0	0.48	1.05
5			-1.55	-1.60	1.0	0.29	1.04
6			-1.15	-1.20	1.0	0.10	1.03
7			-2.25	-1.81	1.5	0.35	0.85
8			-1.85	-1.21	1.5	0.24	0.84
9			-1.45	-0.61	1.5	0	0.83
10			-3.15	-2.03	2.5	0.53	0.66
11			-2.75	-1.03	2.5	0.23	0.65
12			-2.45	-0.28	2.5	0	0.64
13			-6.35	-2.27	6.0	0.47	0.43
14			-6.15	-1.07	6.0	0.24	0.42
15			-5.95	0	6.0	0.02	0.41
16			-3.00	0	3.1	-0.05	0.57
17			-2.00	0	2.2	-0.12	0.68
18			-1.00	0	1.5	-0.26	0.82
19	-0.05	1.0	-0.30	0	1.1	-0.41	0.94
20	-0.2	0.33	-2.10	-3.84	0.3	0.52	1.91
21			-1.30	-3.60	0.3	0.32	1.87
22			-0.30	-3.30	0.3	0.06	1.82
23			-1.30	-1.50	0.5	0.45	1.12
24			-0.80	-1.25	0.5	0.23	1.08
25			-0.30	-1.00	0.5	0	1.03
26			-1.80	-1.21	1.0	0.67	0.76
27			-1.30	-0.71	1.0	0.36	0.69
28			-0.80	-0.21	1.0	0	0.61
29			-1.90	-0.85	1.5	0.52	0.58
30			-1.60	-0.40	1.5	0.29	0.52
31			-1.30	0	1.5	0	0.46
32	-0.2	0.33	-2.90	-1.14	2.5	0.64	0.47

CASE NO.	X_u	$M_u{}^g$	M_q	M_θ	λ	ζ	ω_n
33	-0.2	0.33	-2.60	-0.39	2.5	0.38	0.40
34			-2.40	0	2.5	0.19	0.36
35			-0.30	0	0.9	-0.29	0.62
36		0.33	-3.00	0	3.0	0.24	0.33
37		1.00	-1.80	-3.98	0.5	0.40	1.90
38			-1.30	-3.73	0.5	0.27	1.87
39			-0.70	-3.43	0.5	0.11	1.84
40			-2.80	-2.25	1.0	0.50	1.20
41			-1.40	-1.65	1.0	0.26	1.15
42			-1.00	-1.25	1.0	0.09	1.12
43			-2.10	-1.67	1.5	0.43	0.94
44			-1.70	-1.07	1.5	0.22	0.90
45			-1.40	-0.62	1.5	0.06	0.87
46			-2.70	-0.93	2.5	0.29	0.69
47			-3.00	-1.68	2.5	0.48	0.73
48			-2.30	0	2.5	0	0.63
49			-6.30	-1.97	6.0	0.52	0.48
50			-6.10	-0.77	6.0	0.33	0.44
51			-6.00	0	6.0	0.19	0.41
52			-3.00		3.1	0.07	0.57
53			-1.00		1.5	-0.18	0.82
54	-0.2	1.00	-0.30		1.2	-0.37	0.93
55	-0.05	0.33	-0.30		0.8	-0.38	0.64
56			-1.00		1.2	-0.17	0.52
57			-2.00		2.1	-0.03	0.39
58	-0.05	0.33	-0.60	0	1.0	-0.28	0.58
59	-0.2	1.00	-3.30	-4.74	0.5	0.760	1.975
60	-0.2	1.00	-2.80	-3.05	1.0	0.788	1.269
61	-0.2	1.00	-6.80	-4.64	6.0	0.881	0.567
62	-0.05	0.33	0	-0.133	0.65	-0.415	0.723
63	-0.05	0.33	0	-0.692	0.45	-0.222	0.901
64	-0.05	0.33	0	-1.60	0.25	-0.078	1.286

NOTE: All of the configurations in this table were evaluated with winds and turbulence and with no stick force gradients. All cases were also evaluated as lateral configurations.

TABLE II. CONFIGURATIONS FOR THIRD SIMULATION

CASE NO.	X_u	$M_u K$	M_q	M_θ	Y_v	$L_v K$	L_p	L_ϕ	λ	ω_n	ζ	M_δ and L_δ	λ_{θ_1}	λ_{θ_2}	λ_{θ_3}	λ_{ϕ_1}	λ_{ϕ_2}	λ_{ϕ_3}
301	-0.05	0.330	0	-8.988	-0.05	-0.330	0	-8.988	0.087	3.000	-0.006	-	-	-	-	-	-	-
302			-1.242	-9.125			-1.242	-9.125		3.012	0.200	-	-	-	-	-	-	-
303			-2.455	-9.231			-2.455	-9.231		3.022	0.400	-	-	-	-	-	-	-
304			-4.289	-9.389			-4.289	-9.389		3.038	0.700	-	-	-	-	-	-	-
305			-6.142	-9.550			-6.142	-9.550	0.087	3.053	1.000	-	-	-	-	-	-	-
306			0	-3.992			0	-3.992	0.132	2.000	-0.021	-	-	-	-	-	-	-
307			-0.887	-4.101			-0.887	-4.101		2.011	0.200	-	-	-	-	-	-	-
308			-1.699	-4.209			-1.699	-4.209		2.021	0.400	-	-	-	-	-	-	-
309			-2.933	-4.372			-2.933	-4.372		2.036	0.700	-	-	-	-	-	-	-
310			-4.185	-4.537			-4.185	-4.537	0.132	2.051	1.000	-	-	-	-	-	-	-
311			0	-0.878			0	-0.878	0.374	1.000	-0.162	-	-	-	-	-	-	-
312			-0.731	-1.154			-0.731	-1.154		1.018	0.300	-	-	-	-	-	-	-
313			-1.147	-1.308			-1.147	-1.308		1.028	0.400	-	-	-	-	-	-	-
314			-1.785	-1.547			-1.785	-1.547		1.044	0.700	-	-	-	-	-	-	-
315			-2.443	-1.794			-2.443	-1.794	0.374	1.059	1.000	-	-	-	-	-	-	-
316			-1.123	0			-1.123	0	1.320	0.500	-0.147	-	-	-	-	-	-	-
317			-1.477	-0.467			-1.477	-0.467		0.517	0.200	-	-	-	-	-	-	-
318			-1.692	-0.750			-1.692	-0.750		0.528	0.400	-	-	-	-	-	-	-
319			-2.031	-1.200			-2.031	-1.200		0.544	0.700	-	-	-	-	-	-	-
320		0.330	-2.389	-1.672		-0.330	-2.389	-1.672	1.320	0.560	1.000	-	-	-	-	-	-	-
321		0	-2.000	0		0	-2.000	0	-	-	-	-	0	2.000	0.0500	0	2.000	0.0500
322		-0.005				+0.005			-	-	-	-	-0.0307	2.000	0.0819	-0.0307	2.000	0.0819
323		-0.010				+0.010			-	-	-	-	-0.0492	1.998	0.1017	-0.0492	1.998	0.1017
324		-0.140				+0.140			-	-	-	-	-0.2273	1.963	0.3147	-0.2273	1.963	0.3147
325		-1.000				+1.000			-	-	-	-	-0.5975	1.589	1.0580	-0.5975	1.589	1.0580
326		0				+0.005			-	-	-	-	0	2.000	0.0500	-0.0307	2.000	0.0819
327		0				+0.010			-	-	-	-	0	2.000	0.0500	-0.0492	1.998	0.1017
328		0				+0.140			-	-	-	-	0	2.000	0.0500	-0.2273	1.963	0.3147
329		0				+1.000			-	-	-	-	0	2.000	0.0500	-0.5975	1.589	1.0580
330		-0.005				0			-	-	-	-	-0.0307	2.000	0.0819	0	2.000	0.0500
331		-0.010				0			-	-	-	-	-0.0492	1.998	0.1017	0	2.000	0.0500
332		-0.140				0			-	-	-	-	-0.2273	1.963	0.3147	0	2.000	0.0500
333	-0.05	-1.000	-2.000	0	-0.05	0	-2.000	0	-	-	-	-	-0.5975	1.589	1.0580	0	2.000	0.0500
334	-0.20	0.330	-2.100	-3.840	-0.20	-0.330	-2.100	-3.840	0.300	1.910	0.520	-	-	-	-	-	-	-
335 *			-0.300	-3.300			-0.300	-3.300	0.300	1.820	0.060	-	-	-	-	-	-	-
336			-1.800	-1.210			-1.800	-1.210	1.000	0.760	0.670	-	-	-	-	-	-	-
337			-0.800	-0.210			-0.800	-0.210	1.000	0.610	0	-	-	-	-	-	-	-
338			-2.100	-3.840			-2.100	-3.840	0.300	1.910	0.520	-	-	-	-	-	-	-
339			-0.300	-3.300			-0.300	-3.300	0.300	1.820	0.060	-	-	-	-	-	-	-
340			-1.800	-1.210			-1.800	-1.210	1.000	0.760	0.670	-	-	-	-	-	-	-
341			-0.800	-0.210			-0.800	-0.210	1.000	0.610	0	-	-	-	-	-	-	-
342			-2.100	-3.840			-2.100	-3.840	0.300	1.910	0.520	-	-	-	-	-	-	-
343 †			-0.300	-3.300			-0.300	-3.300	0.300	1.820	0.060	-	-	-	-	-	-	-
344			-1.800	-1.210			-1.800	-1.210	1.000	0.760	0.670	-	-	-	-	-	-	-
345	-0.20		-0.800	-0.210	-0.20		-0.800	-0.210	1.000	0.610	0	-	-	-	-	-	-	-
346	-0.05		-4.289	-9.389	-0.05		-4.289	-9.389	0.087	3.038	0.700	0.300	-	-	-	-	-	-
347												0.450	-	-	-	-	-	-
348												1.350	-	-	-	-	-	-
349												4.050	-	-	-	-	-	-
350			-4.289	-9.389			-4.289	-9.389	0.087	3.038		6.075	-	-	-	-	-	-
351			-2.933	-4.372			-2.933	-4.372	0.132	2.036		0.300	-	-	-	-	-	-
352												0.450	-	-	-	-	-	-
353												1.350	-	-	-	-	-	-
354												4.050	-	-	-	-	-	-
355			-2.993	-4.372			-2.933	-4.372	0.132	2.036		6.075	-	-	-	-	-	-
356			-1.785	-1.547			-1.785	-1.547	0.374	1.044		0.300	-	-	-	-	-	-
357												0.450	-	-	-	-	-	-
358												1.350	-	-	-	-	-	-
359												4.050	-	-	-	-	-	-
360	-0.05	0.330	-1.785	-1.547	-0.05	-0.330	-1.785	-1.547	0.374	1.044	0.700	6.075	-	-	-	-	-	-

Note All of the configurations in this table were evaluated with winds and turbulence and with stick force gradients except as follows:

* Cases 334 through 337 had no winds or turbulence and no stick force gradients.

† Cases 342 through 345 had no winds or turbulence.

SECTION VI

RESULTS

This section is composed of pilot ratings and pilot-selected control sensitivities in tabular form for each simulation; s-plane plots of pilot ratings for the first and second simulations; s-plane plots of pilot ratings for cases 301-320 and 334-345 of the third simulation; pilot ratings and control sensitivities for cases 321-333 on a plot of $L_v g$ vs - $M_u g$; pilot ratings and control sensitivities for cases 321-333 plotted against $L_v g$ and/or- $M_u g$; pilot ratings for cases 346-350 plotted against control sensitivity; pilot tracking performance; probability density plots of δ_e and M_c and power spectral density plots of δ_e for certain selected cases.

In the first simulation (Tables III and IV), each pilot flew two-thirds of the configurations. Hence, each configuration was evaluated by two pilots. The configurations assigned each pilot were selected at random. Each configuration was then evaluated as a longitudinal configuration and as the corresponding lateral configuration. The order of testing was at random, with the pilot flying a group of about 10 longtitudinal configurations and then the corresponding lateral configurations. A few cases were rerun and these are indicated in the tables compiled in this section.

The second simulation (Table V) consisted of a number of repeat configurations and six new configurations. The repeat configurations were assigned to each pilot on an individual basis after examining the results of the first simulation. The new configurations were assigned such that each configuration was evaluated by two pilots.

The third simulation (Table VI) consisted of 60 configurations, with each configuration evaluated by all three pilots. The pilots selected both the pitch and roll control sensitivities for cases 301 through 345. For cases 346 through 360, the control sensitivities were fixed. A number of the cases were rerun by each pilot as indicated in Table VII.

In Figures 21 through 28, pilot ratings for the first and second simulations are shown on s-plane plots. In these plots the pilot rating for a rerun was used rather than for the original run, if a rerun was performed. The pilot ratings given in parenthesis are from the second simulation.

In Figures 29 through 32, pilot ratings for cases 301-320 and 334-345 of the third simulation are shown on s-plane plots. Again, the rating for a rerun was used if a rerun was performed.

For cases 321-333 the pilot ratings are presented on a plot of $L_v g$ vs - $M_u g$ in Figure 33. These cases are all configurations in which M_θ and L_ϕ are zero, and M_q and L_p are constant at values of -2.000. In Figures 34, 37, and 40 pilot ratings and

pilot-selected control sensitivities are plotted against $-M_ug$ and L_vg for cases 321-325 ($-M_ug = L_vg$); in Figures 35, 38, and 41 pilot ratings and sensitivities are plotted against L_vg for cases 326-329 and 321 ($M_ug = 0$); in Figures 36, 39 and 42 pilot ratings and sensitivities are plotted against $-M_ug$ for cases 330-333 and 321 ($L_vg = 0$). Again, reruns are used in all of these plots where applicable.

For cases 346-350, 351-355, and 356-360 pilot ratings are plotted against control sensitivities in Figures 43 through 45. The control sensitivities for these cases were set at preselected values and were equal in pitch and roll. Cases 346-350 were the same as case 304 except for control sensitivity. The sensitivities selected by the pilots and the pilot ratings for case 304 are given in Figure 43. Similarly, cases 351-355 were the same as case 309, and cases 356-360 were the same as case 314.

A measure of the pilots' tracking performance in the air-taxi-around-the-square is presented in Figures 46 through 57. The aircraft path over the ground during this portion of each flight was recorded on an x-y plotter. Using these plots, a performance index for each flight was calculated as follows: The square was 80 feet on a side but inasmuch as the pilot hovered the aircraft at the corners, the first and last 10 feet of each leg was disregarded. This left 60 feet on a side or 240 feet for all four legs. The performance index is the fraction of this 240 feet that the aircraft was outside of the ± 5-foot limits. On the sideways legs, it was a little difficult for the pilot to see the ground pattern in the simulator and some of the pilots preferred to fly these legs back of the groundline in order to see it better. Hence, when evaluating the plots, the square was shifted if it would improve the performance index. In a few cases, the x-y plots were not obtained, so by necessity no value is given for performance index for these cases. Shown on the same chart with the performance index is the pilot rating. Obviously, the lines on the charts connecting the pilot rating points and those connecting the performance index values have no meaning. They are merely there to connect the points for ease in observing the charts.

For cases 120, 139, 314, 356, and 360, probability density plots are given in Appendix III for control stick travel and for control input. Power spectral density plots of stick travel for these cases are also presented.

Case 120 is a configuration with relatively high natural frequency and moderately high damping ratio. Its location in the s-plane is shown in Figure 23. Case 139 is also a case with relatively high natural frequency but with low damping ratio. Its location in the s-plane is shown in Figure 25. For both of these cases, Pilot B chose a higher control sensitivity than did Pilot C. Both of these cases have a high X_u. Case 120 has a low M_ug; Case 139, a high M_ug.

Case 314 is chosen from the low X_u, low M_ug cases. Its location in the s-plane is shown in Figure 29. Cases 356 and 360 have the same dynamics as Case 314 but were tested with fixed control sensitivity, whereas in case 314 the pilot selected the control sensitivity. Case 356 had a low value of control sensitivity; Case 360, a high value. In case 314, the pilot selected a value of control sensitivity between the other two values.

The δ_e signal that was processed for these plots includes trim. The M_c signal is composed of the input to the aircraft due to δ_e, pitch rate, and pitch attitude, i.e.,

$M_c = M_\delta \delta_e + M_q q + M_\theta \theta$. The sign convention for δ_e is positive for stick forward. Positive M_c is a nose-up pitching moment. On a number of the probability density plots the sign of the abscissa is such that positive sense is to the left. The definition of σ as used in these plots is that it is the positive square root of the second moment of y (t) about the mean value, m, of the sample where y (t) is the sample voltage time history. That is,

$$\sigma^2 = \frac{1}{T} \int_0^T x^2 (t)\, dt = \frac{1}{T} \int_0^T \left[y (t) - m\right]^2 dt$$

t is the sampling time and x (t) is the sample voltage time history less the mean value, m. The mean value is not determined numerically by the processing analyzer but an indication of the mean value can be obtained by noting the offset of the probability density peak from zero.

A discussion of the processing of the data to obtain these plots also is presented in Appendix III.

TABLE III. PILOT RATINGS FOR FIRST SIMULATION

CASE NO	PILOT A	PILOT B	PILOT C	CASE NO.	PILOT A	PILOT B	PILOT C
101	3	4	-	201	2	4	-
102	3	-	6	202	4	-	3-1/2
103	7	-	6	203	6	-	5
104	3	4	-	204	5	3	-
105	-	5	6	205	-	4	3
106	-	4	4-1/2	206	-	6	2
107	-	4	6	207	-	4	3
108	2	4	-	208	2-1/2	3	-
109	3-1/2	-	4	209	2	-	5
110	3	-	2	210	1-1/2	-	2
111	-	4	3	211	-	4	4
112	4	-	2	212	2	-	3
113	3	-	1-1/2	213	2	-	1-1/2
114	-	3	2	214	-	3	2
115	5	4	-	215	3	2	-
116	3-1/2	5	-	216	2	3-1/2	-
117	-	5	5	217	-	5	5
118	-	5	5	218	-	5	3
119	5	6	-	219	5	10	-
120	-	5	7	220	-	5	4-1/2
121	6	-	6	221	4-1/2	-	6
122	6-1/2	-	3	222	5	-	7
123	-	5-1/2	6	223	-	5	6
124	8	8	-	224	7	7	-
125	7	-	9	225	4 (5)*	-	8
126	4-1/2	-	5	226	4-1/2	-	5
127	5	-	2	227	5	-	6
128	7	9	-	228	7	7	-
129	5	-	7	229	5	-	5
130	3-1/2	6	-	230	4-1/2	5	-
131	-	8	6	231	-	7	8
132	-	6	4	232	-	7	7
133	4	6	-	233	4	7	-
134	4-1/2	7	-	234	5	7	-
135	6-1/2	-	7	235	7	-	9
136	4	6	-	236	4	4	-
137	-	5	7	237	-	5	9 (8)*
138	-	8	6	238	-	6	3 (4)*
139	-	9	7	239	-	9	7
140	3-1/2	7	-	240	3	5	-
141	-	4 (6-1/2)*	8	241	-	7	7
142	6	-	5	242	7	-	8
143	5	7	-	243	5	6	-
144	6	-	4	244	5	-	5-1/2
145	4	7	-	245	4	6	-
146	-	5	6	246	-	6	7
147	2	6	-	247	4-1/2	6	-
148	5	-	5	248	5-1/2	-	7
149	3	5	-	249	2-1/2	5	-
150	5	-	2	250	4	-	5
151	3	6	-	251	3	5	-
152	-	8*	7	252	-	5	5
153	7	9	-	253	6	5	-
154	4-1/2 (7)*	10	-	254	7	10	-
155	4	-	3	255	6	-	9
156	-	3	2	256	-	4-1/2	6
157	-	4	2	257	-	3	2-1/2
158	4-1/2	-	8	258	5	-	4

*Rerun

TABLE IV. CONTROL SENSITIVITIES FOR FIRST SIMULATION

CASE NO	M_δ PILOT A	M_δ PILOT B	M_δ PILOT C	CASE NO.	L_δ PILOT A	L_δ PILOT B	L_δ PILOT C
101	1 240	869	-	201	2 000	850	-
102	1 027	-	416	202	1.141	-	418
103	963	-	404	203	1 069	-	420
104	1.989	.712	-	204	314	1.069	-
105	-	697	497	205	-	740	428
106	-	735	444	206	-	870	482
107	-	745	265	207	-	768	427
108	1 157	797	-	208	1 476	1 431	-
109	1 308	-	410	209	1 414	-	612
110	1 636	-	421	210	2.000	-	616
111	-	790	290	211	-	1 635	378
112	945	-	484	212	1.558	-	.558
113	1.860	-	.463	213	2 000	-	.812
114	-	1 346	373	214	-	2 000	427
115	1 978	951	-	215	2 000	2.000	-
116	1 500	1 502	-	216	1 784	1.721	-
117	-	803	295	217	-	793	.433
118	-	955	370	218	-	.785	639
119	728	.676	-	219	1.800	1 211	-
120	-	819	446	220	-	1 309	595
121	1 236	-	472	221	1 833	-	746
122	1.045	-	324	222	1.383	-	605
123	-	746	271	223	-	716	513
124	1 218	704	-	224	1 289	937	-
125	1 309	-	409	225	1 408(978)*	-	506
126	1.261	-	.365	226	2.000	-	529
127	1.358	-	350	227	1 437	-	665
128	.490	745	-	228	1 087	.747	-
129	1 142	-	257	229	2 000	-	.590
130	1.056	823	-	230	2.000	1.058	-
131	-	777	393	231	-	771	360
132	-	710	297	232	-	762	.763
133	1.348	1.124	-	233	1 632	1 365	-
134	1 368	831	-	234	2 000	2.000	-
135	1 198	-	400	235	1.235	-	.421
136	1 437	1 125	-	236	1 011	1 297	-
137	-	.753	529	237	-	.741	.929(995)*
138	-	805	369	238	-	757	561(.598)*
139	-	653	471	239	-	606	360
140	1.400	1 051	-	240	2 000	1 310	-
141	-	682(809)*	350	241	-	788	560
142	1 316	-	441	242	1 037	-	551
143	1 369	.812	-	243	1 765	1.141	-
144	.411	-	412	244	2 000	-	584
145	1.128	845	-	245	1 195	1 192	-
146	-	738	300	246	-	1 375	488
147	819	1 009	-	247	1 337	1 173	-
148	1 365	-	163	248	1 769	-	609
149	2 000	1 407	-	249	2 000	2 000	-
150	2 000	-	797	250	2 000	-	848
151	2 000	1 555	-	251	1 727	1 689	-
152	-	826	439	252	-	890	639
153	924	788	-	253	2 000	1 350	-
154	1 030	.673	-	254	1 730	949	-
155	920	-	.559	255	2 000	-	604
156	-	380	459	256	-	703	493
157	-	727	401	257	-	815	470
158	1 036	-	233	258	1 238	-	465

*Rerun

TABLE V. PILOT RATINGS AND CONTROL SENSITIVITIES FOR SECOND SIMULATION

CASE NO.	PR			M_δ		
	PILOT A	PILOT B	PILOT C	PILOT A	PILOT B	PILOT C
102	4-1/2	-	4	1.253	-	.457
105	-	-	5	-	-	.458
106	-	3	-	-	.729	-
107	-	-	3	-	-	.317
112	3	-	4	1.381	-	.653
115	5	-	-	1.963	-	-
116	-	5	-	-	.907	-
122	-	-	7	-	-	.434
125	-	-	6	-	-	.432
127	-	-	4	-	-	.382
128	-	8	-	-	1.057	-
130	5	-	-	1.099	-	-
137	-	-	5	-	-	.508
140	5	6	5	1.272	.893	.377
141	6	5	5	1.169	.700	.498
143	-	4-1/2	-	-	.791	-
145	6	-	-	1.282	-	-
147	6	5	5	1.328	.820	.425
150	-	-	5	-	-	.371
151	4	6	-	1.213	1.407	-
153	-	8	-	-	.956	-
154	-	7	-	-	.707	-
155	4	-	7	1.046	-	.454
157	-	4-1/2	-	-	1.067	-
158	3	-	6	.887	-	.382
159	-	5	6	-	.942	.541
160	6	-	4	1.276	-	.499
161	6	5-1/2	-	1.637	1.280	-
162	-	6	7	-	.707	.299
163	4	-	8	.848	-	.420
164	3	3	-	.887	.729	-

CASE NO.	PR			L_δ		
	PILOT A	PILOT B	PILOT C	PILOT A	PILOT B	PILOT C
204	2-1/2	-	-	1.449	-	-
206	-	-	6	-	-	1.109
212	3	-	5-1/2	1.487	-	.903
218	-	-	6	-	-	.689
219	7	5	-	1.265	.837	-
225	6	-	-	1.804	-	-
232	-	4-1/2	6	-	1.459	.603
233	-	5	-	-	1.294	-
234	-	4	-	-	1.055	-
237	-	-	8	-	-	.661
240	6	-	-	2.000	-	-
249	5	3-1/2	-	2.000	1.788	-
254	-	9-1/2	-	-	.970	-
255	-	-	8	-	-	.422
259	-	3	7	-	1.770	.906
260	4	-	5	1.924	-	.960
261	4	3	-	4.000	2.000	-
262	-	10	7	-	1.118	.528
263	6	-	8	1.247	-	.403
264	7	10	-	1.448	.953	-

TABLE VI. PILOT RATINGS AND CONTROL SENSITIVITIES FOR THIRD SIMULATION

CASE NO.	PILOT D			PILOT E			PILOT F		
	PR	M_δ	L_δ	PR	M_δ	L_δ	PR	M_δ	L_δ
301	5	0.729	0.827	5	0.605	0.627	2-1/2	0.903	0.946
302	[illegible]	0.545	0.705	4-1/2	0.503	0.768	2-1/2	1.357	1.306
303	2-1/2	1.005	0.763	3	0.738	0.733	2-1/2	1.166	1.205
304	3	0.772	1.064	2-1/2	0.724	0.895	1-1/2	1.776	1.788
305	4	0.866	1.320	2	0.965	1.044	1	0.584	0.588
306	5-1/2	0.908	1.096	7	0.525	0.485	3	0.581	0.624
307	4	0.310	0.587	4	0.358	0.368	2	0.683	0.695
308	4	0.528	0.681	3	0.496	0.760	2-1/2	0.850	0.710
309	2-1/2	0.532	0.557	2-1/2	0.563	0.625	2	0.774	0.817
310	2	0.681	0.585	3	0.893	0.889	1-1/2	0.716	0.759
311	7	0.726	0.522	7-1/2	0.201	0.233	2	0.417	0.463
312	5	1.121	1.104	4	0.586	0.593	3	0.457	0.501
313	5	0.709	1.062	3	0.330	0.251	4	0.662	0.705
314	5	0.615	0.951	2-1/2	0.586	0.494	3	0.366	0.379
315	5	0.483	0.369	3	0.437	0.472	2	0.550	0.562
316	7	1.093	1.950	5	0.436	0.406	3	0.453	0.474
317	6	1.040	1.791	5	0.910	0.875	3	0.829	0.874
318	6	0.653	1.442	5	0.465	0.498	3	0.456	0.569
319	5-1/2	1.346	1.317	3	0.321	0.329	4	0.828	0.841
320	5	0.614	0.920	4	0.644	0.536	2-1/2	0.742	0.785
321	4	0.774	0.961	5	0.393	0.409	2-1/2	0.609	0.621
322	4	0.569	0.922	4	1.120	1.081	2-1/2	0.553	0.569
323	4-1/2	0.714	0.994	3	0.459	0.496	3	0.634	0.677
324	4	0.601	0.884	3	0.626	0.596	2	0.539	0.552
325	7	0.717	1.069	6	0.893	0.900	4	0.753	0.770
326	4	0.618	0.902	4-1/2	0.453	0.467	2-1/2	0.416	0.428
327	4	0.574	0.736	5	0.469	0.485	2	0.500	0.584
328	5	0.720	1.022	4-1/2	0.421	0.363	5	0.431	0.509
329	5	0.668	0.947	7	0.656	0.652	3	0.820	0.863
330	5	0.836	1.154	7	0.391	0.458	3	0.838	0.866
331	5	0.696	1.200	7	0.908	0.734	2-1/2	0.919	0.863
332	5	0.595	1.100	8	0.794	0.789	2-1/2	0.669	0.713
333	6	0.886	1.017	7	0.358	0.339	4	0.727	0.739
334	4	0.800	1.552	3	0.883	0.891	2	0.749	0.766
335 *	4	0.712	0.997	4	0.573	0.579	2	0.700	0.718
336	4	0.860	0.938	3	0.884	0.891	3	0.862	0.879
337	4	0.830	1.245	5-1/2	0.644	0.648	2-1/2	0.717	0.73[illegible]
338	7	2.628	1.000	7	0.469	0.453	7	0.855	0.867
339	7	0.856	1.116	8	0.309	0.273	7	0.734	0.777
340	7	0.887	1.149	7	0.814	0.835	7	1.021	1.061
341	7	0.674	0.952	10	0.466	0.501	7	0.617	0.429
342	3	0.830	0.922	2-1/2	0.893	0.900	2	0.694	0.711
343 †	3	0.619	0.709	4-1/2	0.258	0.293	2	0.575	0.480
344	4	0.925	1.017	2-1/2	0.609	0.643	3	0.569	0.582
345	4	0.649	0.741	3	0.486	0.433	3	0.719	0.763
346	6	0.300	0.300	7	0.300	0.300	3	0.300	0.300
347	5	0.450	0.450	6	0.450	0.450	1	0.450	0.450
348	1	1.350	1.350	2	1.350	1.350	3	1.350	1.350
349	7	4.050	4.050	7	4.050	4.050	7	4.050	4.050
350	8	6.075	6.075	7	6.075	6.075	7	6.075	6.075
351	5	0.300	0.300	5	0.300	0.300	2-1/2	0.300	0.300
352	5	0.450	0.450	2-1/2	0.450	0.450	2	0.450	0.450
353	1	1.350	1.350	3	1.350	1.350	2-1/2	1.350	1.350
354	7	4.050	4.050	8	4.050	4.050	9	4.050	4.050
355	9	6.075	6.075	9	6.075	6.075	9	6.075	6.075
356	5	0.300	0.300	4-1/2	0.300	0.300	1-1/2	0.300	0.300
357	5	0.450	0.450	4-1/2	0.450	0.450	2	0.450	0.450
358	6	1.350	1.350	5-1/2	1.350	1.350	5	1.350	1.350
359	8	4.050	4.050	8	4.050	4.050	9	4.050	4.050
360	8	6.075	6.075	8-1/2	6.075	6.075	9	6.075	6.075

NOTE For Cases 346-360, the control sensitivities were fixed, i.e., they were not selected by the pilots.
*Cases 334 through 337 had no winds or turbulence and no stick force gradients.
†Cases 342 through 345 had no winds or turbulence.

TABLE VII. THIRD SIMULATION RERUNS

CASE NO. (RERUNS)	PILOT D			PILOT E			PILOT F		
	PR	M_δ	L_δ	PR	M_δ	L_δ	PR	M_δ	L_δ
302	5	0.886	1.201	-	-	-	-	-	-
303	2-1/2	0.979	1.025	-	-	-	-	-	-
304	-	-	-	3	1.078	1.100	-	-	-
305	3	1.012	1.052	-	-	-	-	-	-
311	-	-	-	-	-	-	2-1/2	0.628	0.646
314	-	-	-	4-1/2	0.830	0.851	-	-	-
316	-	-	-	6	0.829	0.851	-	-	-
319	-	-	-	3	0.767	0.789	-	-	-
324	5	0.853	1.176	-	-	-	-	-	-
327	-	-	-	5	0.829	0.851	-	-	-
328	-	-	-	-	-	-	[illegible]	0.771	0.750
329	-	-	-	-	-	-	4	0.773	0.752
332	-	-	-	7	0.813	0.835	-	-	-
338	7	0.854	1.171	-	-	-	-	-	-
343	4-1/2	0.746	1.062	-	-	-	4	0.757	0.736
347	-	-	-	-	-	-	3	0.450	0.450
352	-	-	-	1	0.450	0.450	-	-	-
356	-	-	-	-	-	-	4	0.300	0.300
357	-	-	-	-	-	-	3	0.450	0.450
358	4-1/2	1.350	1.350	-	-	-	-	-	-

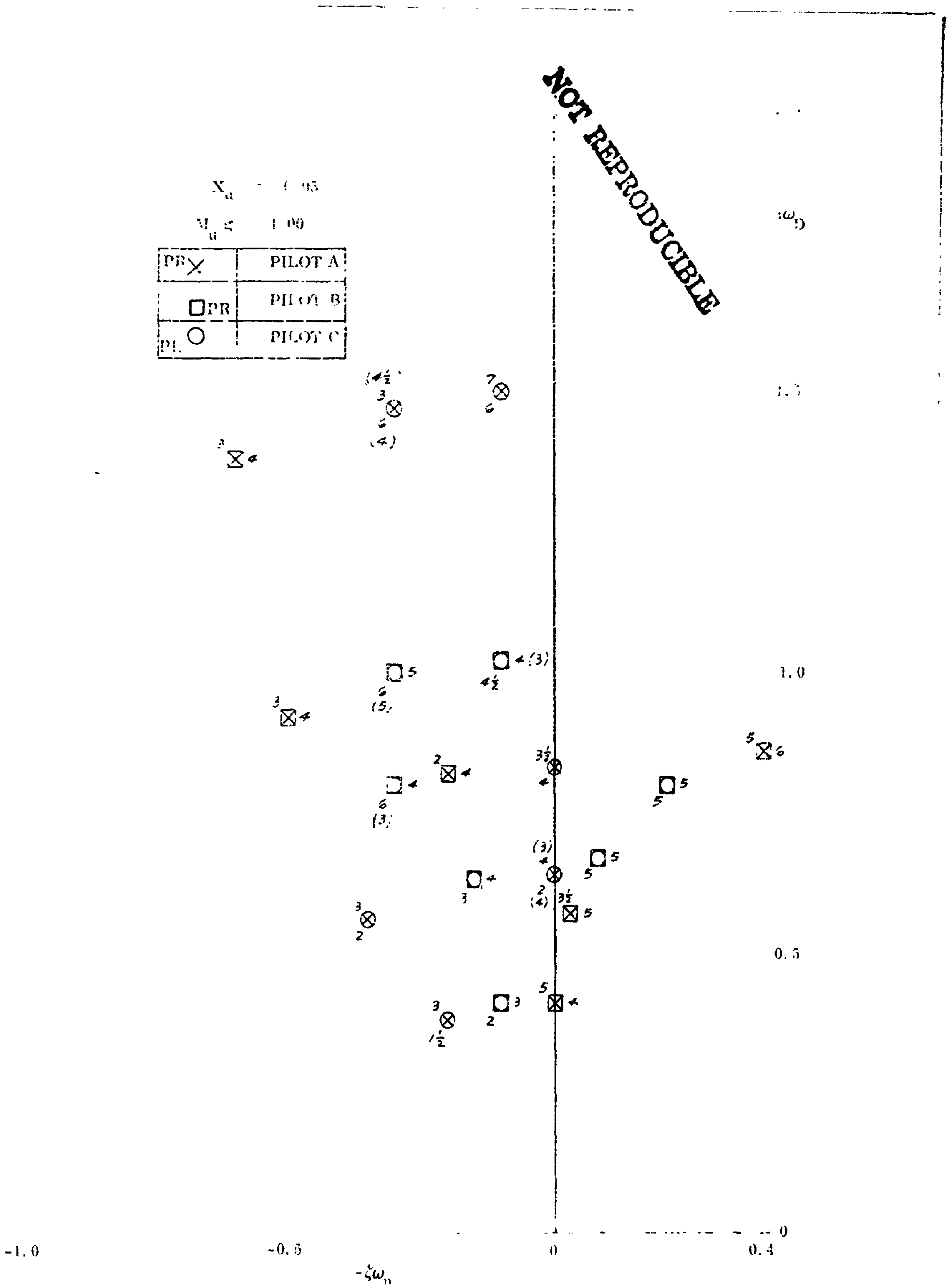


FIGURE 21. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS - CASES 101-119

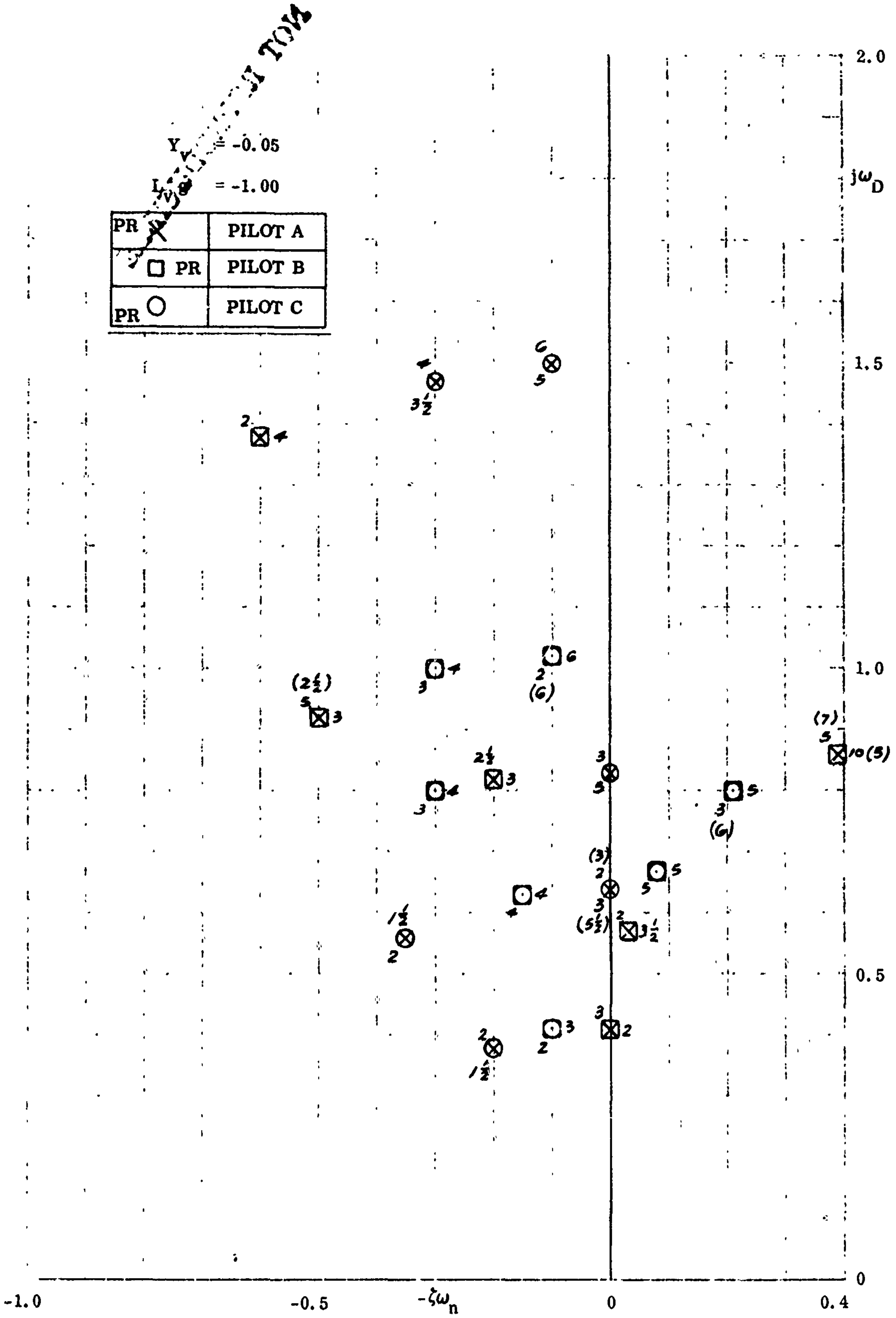


FIGURE 22. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS — CASES 201-219

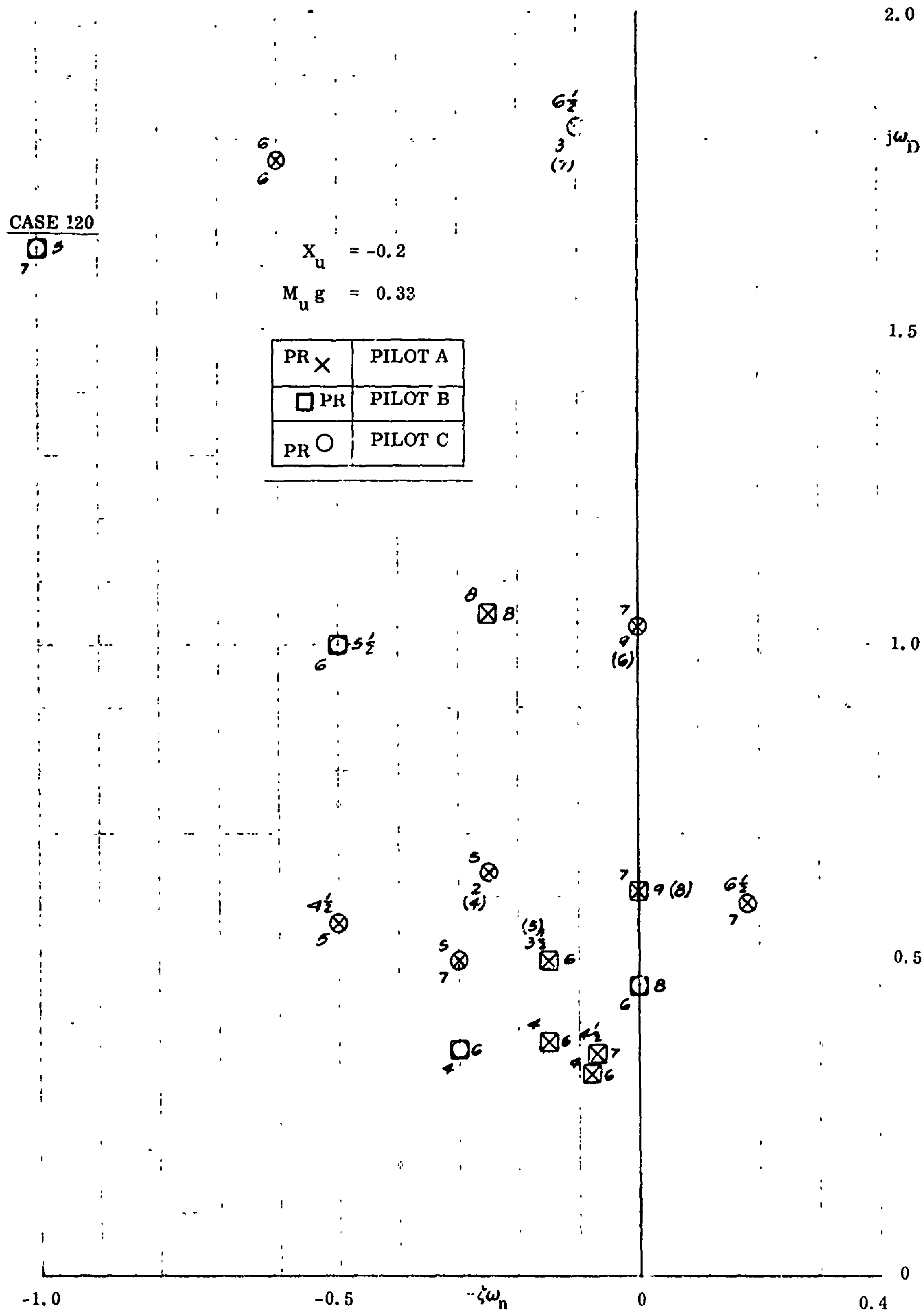


FIGURE 23. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS - CASES 120-136

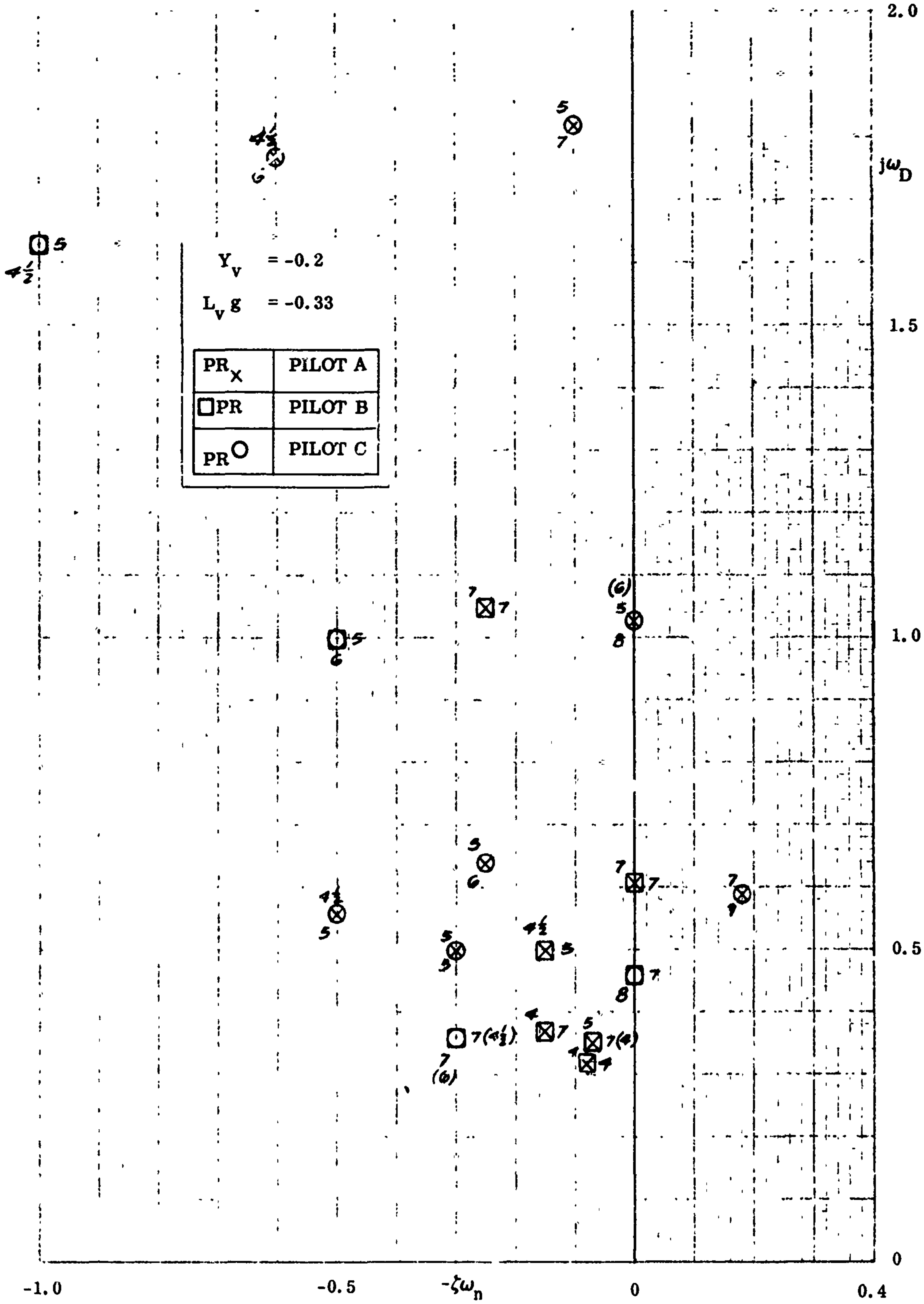


FIGURE 24. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS - CASES 220-236

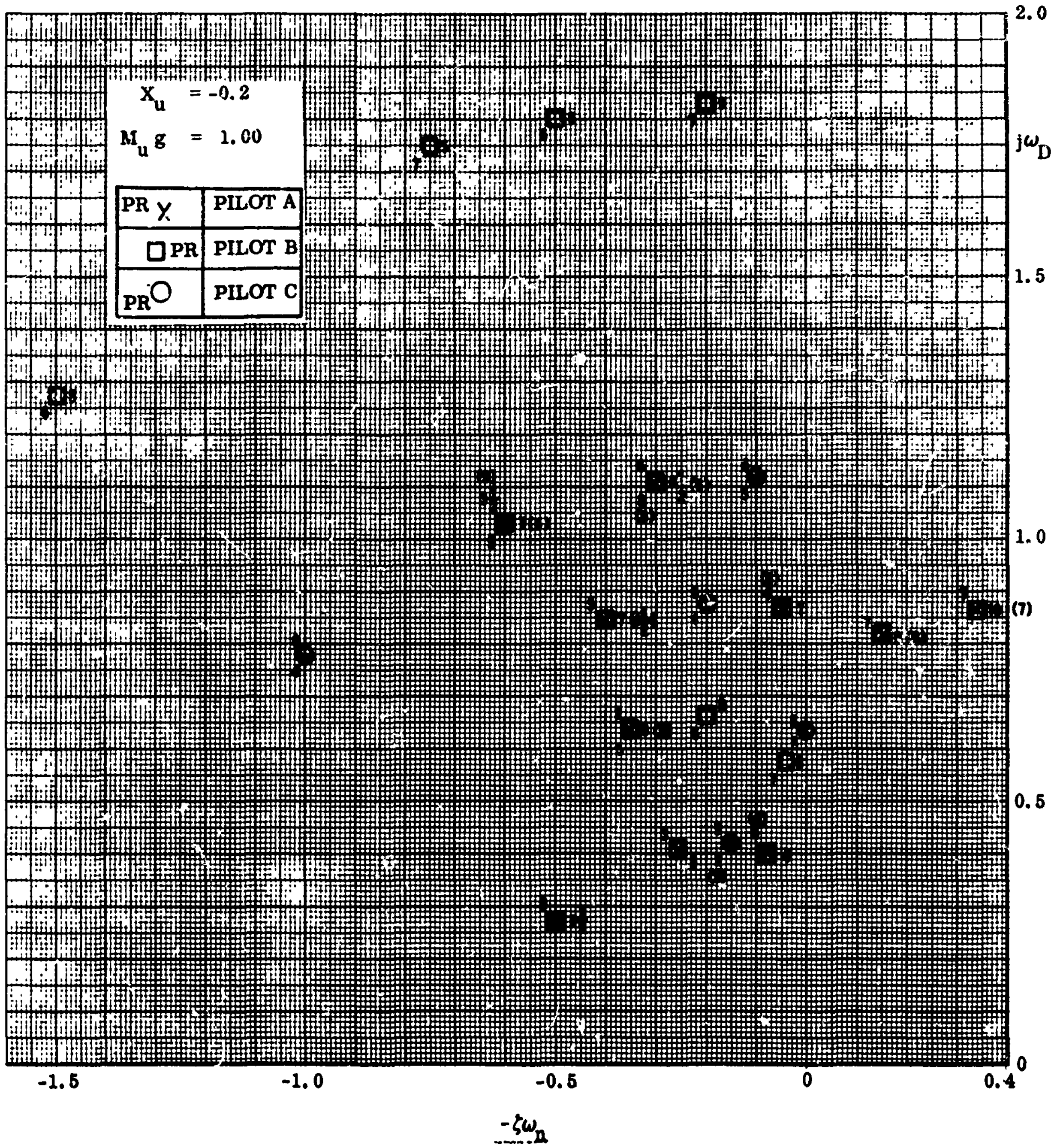


FIGURE 25. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS - CASES 137-154, 159-161

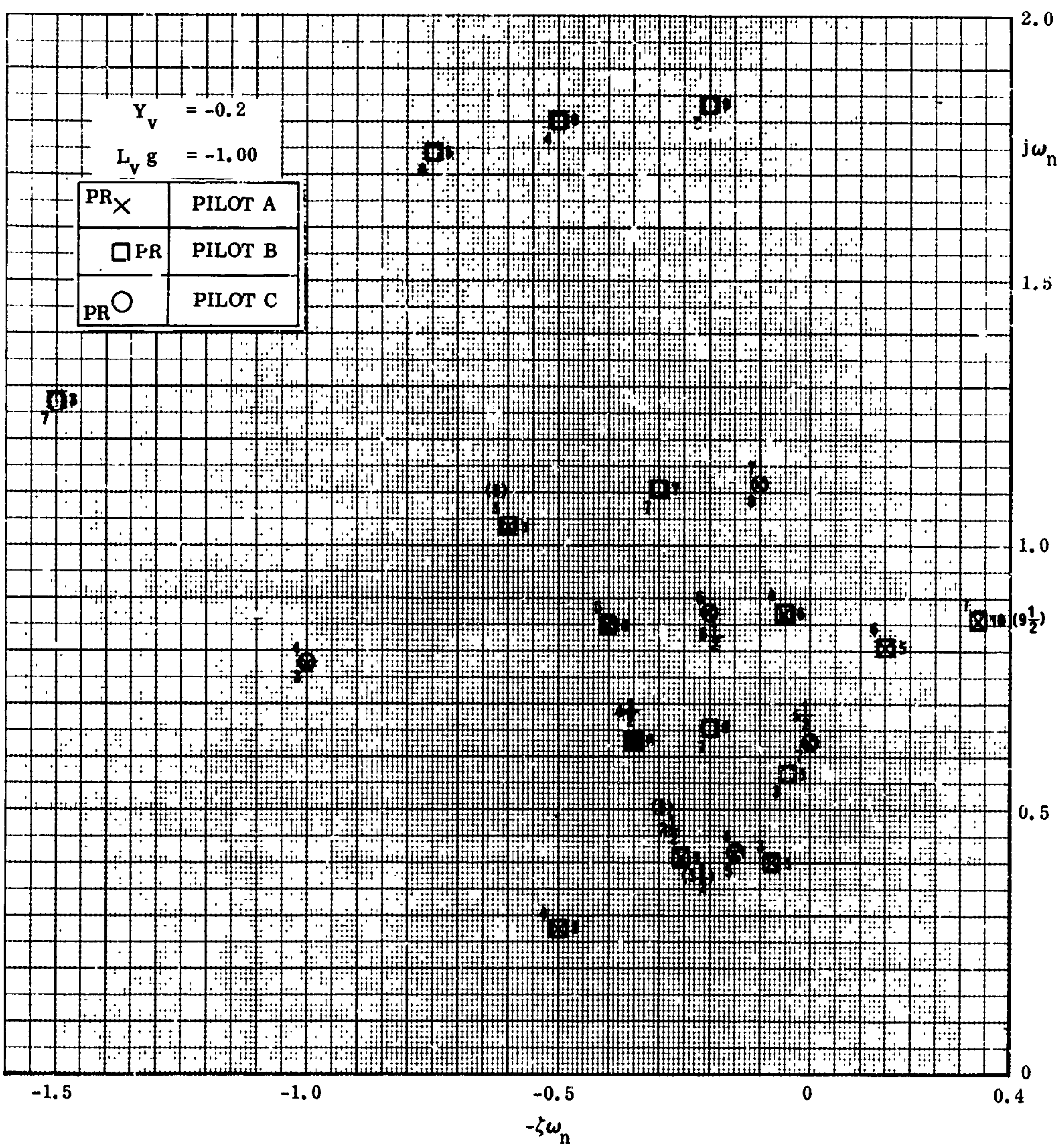


FIGURE 26. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS - CASES 237-254, 259-261

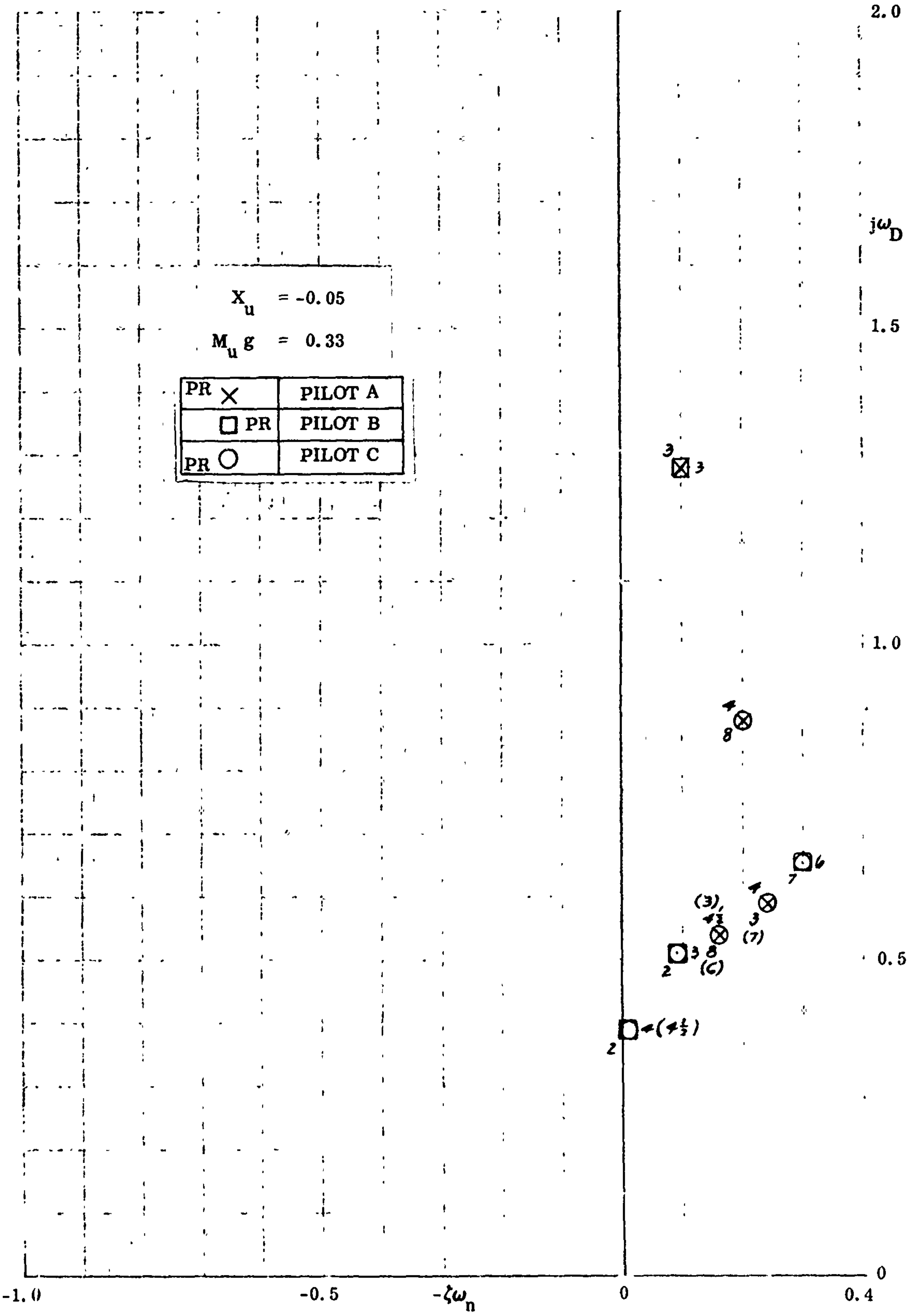


FIGURE 27. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS - CASES 155-158, 162-164

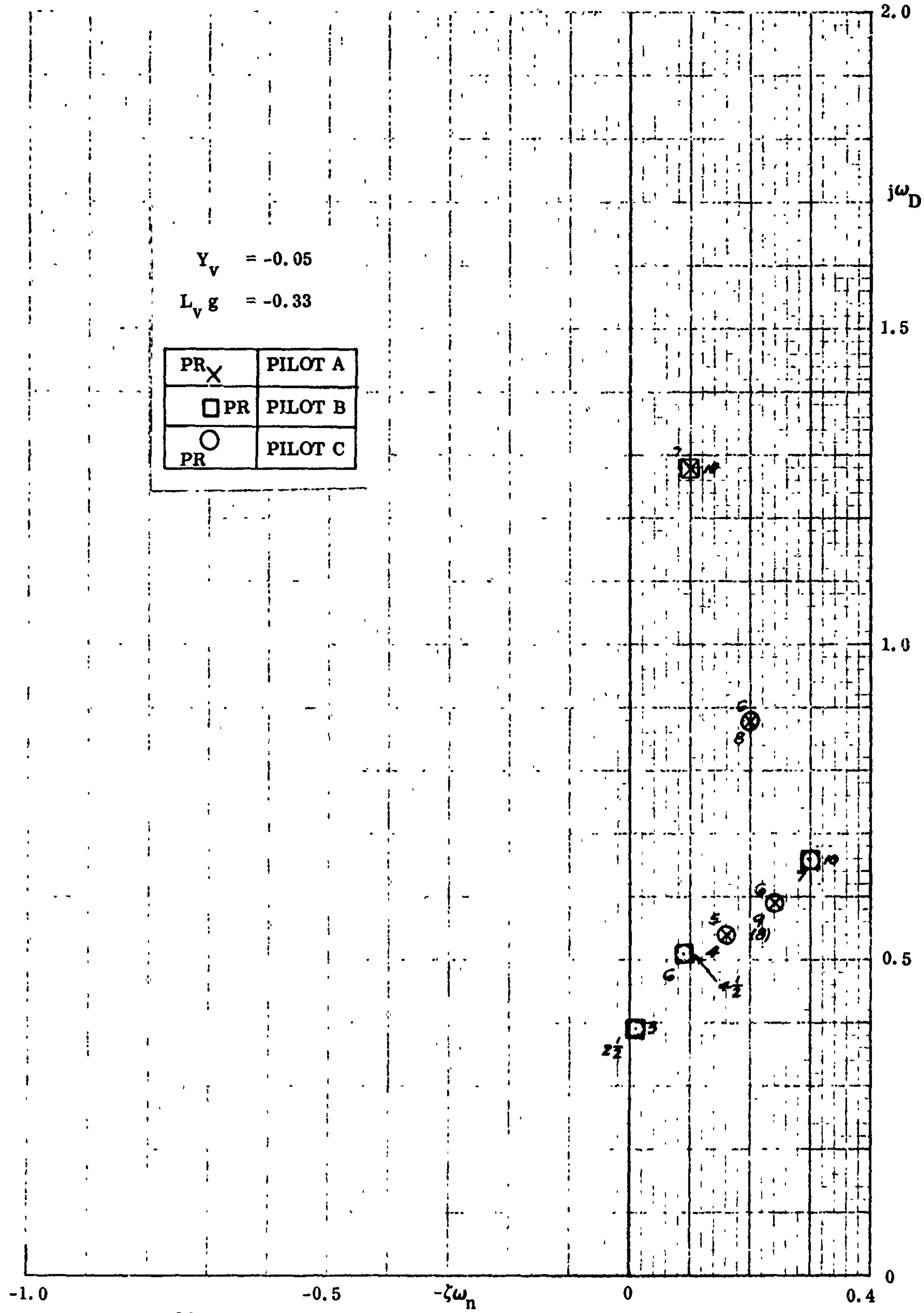


FIGURE 28. PILOT RATINGS FOR FIRST AND SECOND SIMULATIONS - CASES 255-258, 262-264

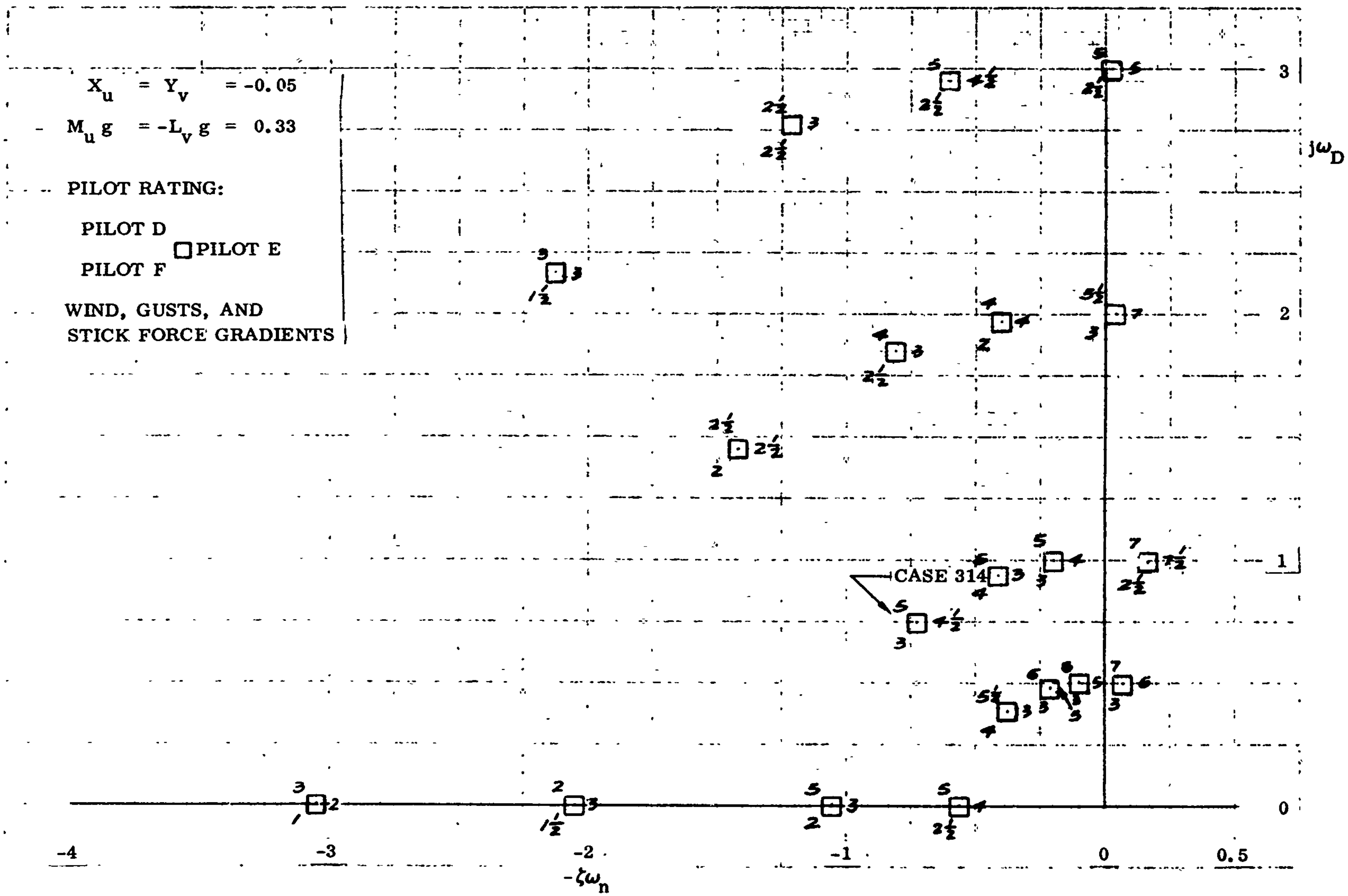


FIGURE 29. PILOT RATINGS FOR THIRD SIMULATION - CASES 301-320

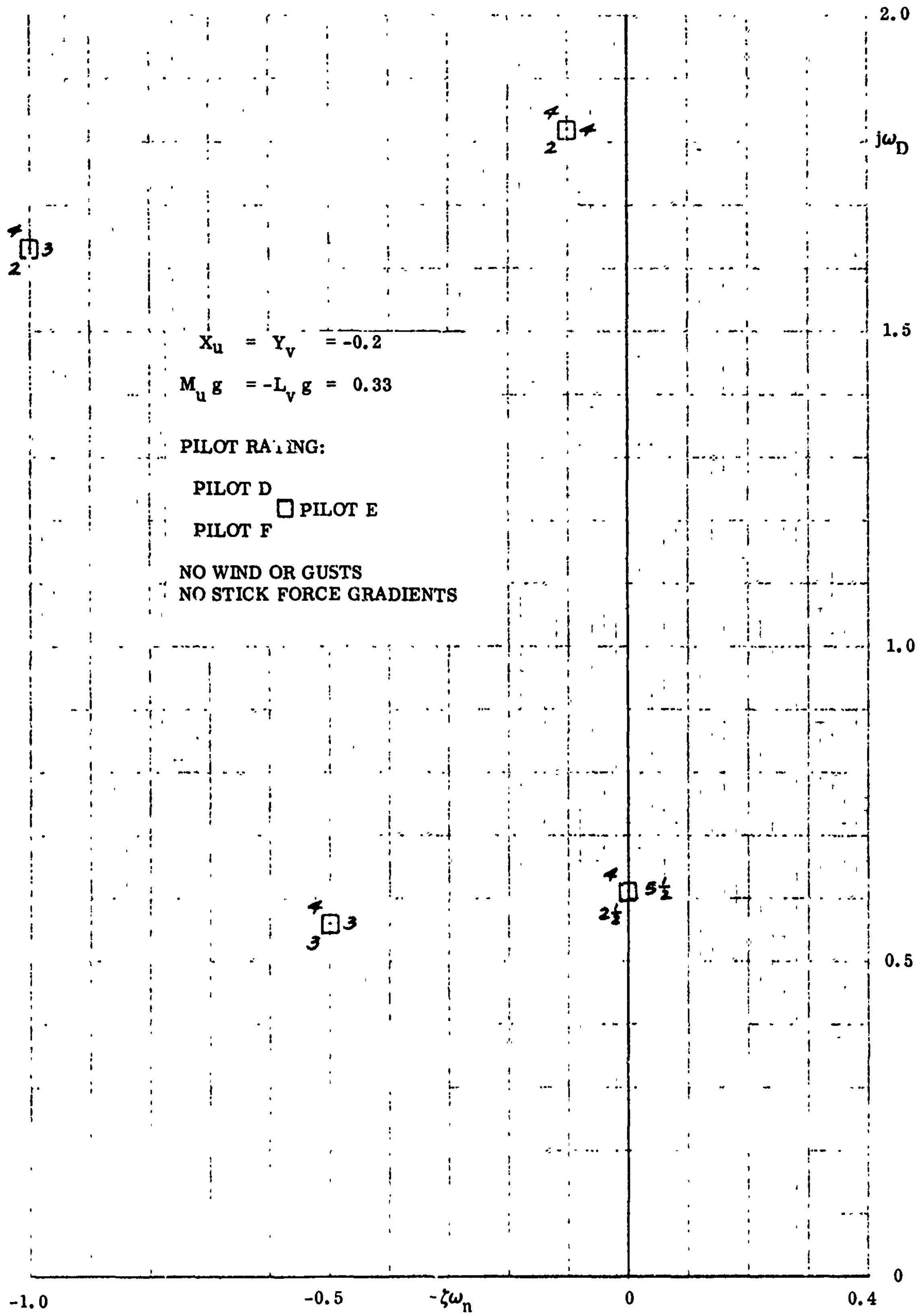


FIGURE 30. PILOT RATINGS FOR THIRD SIMULATION - CASES 334-337

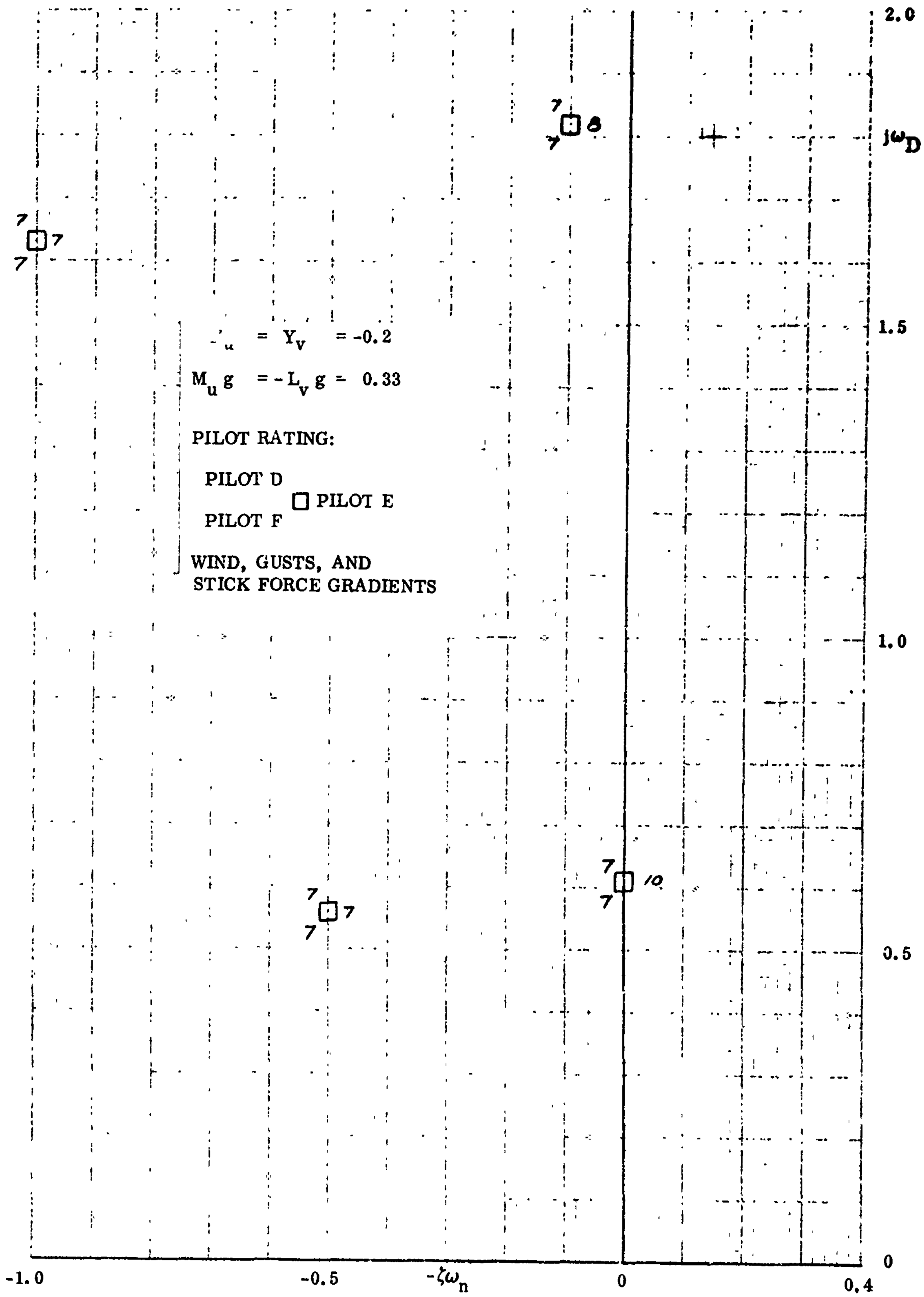


FIGURE 31. PILOT RATINGS FOR THIRD SIMULATION - CASES 338-341

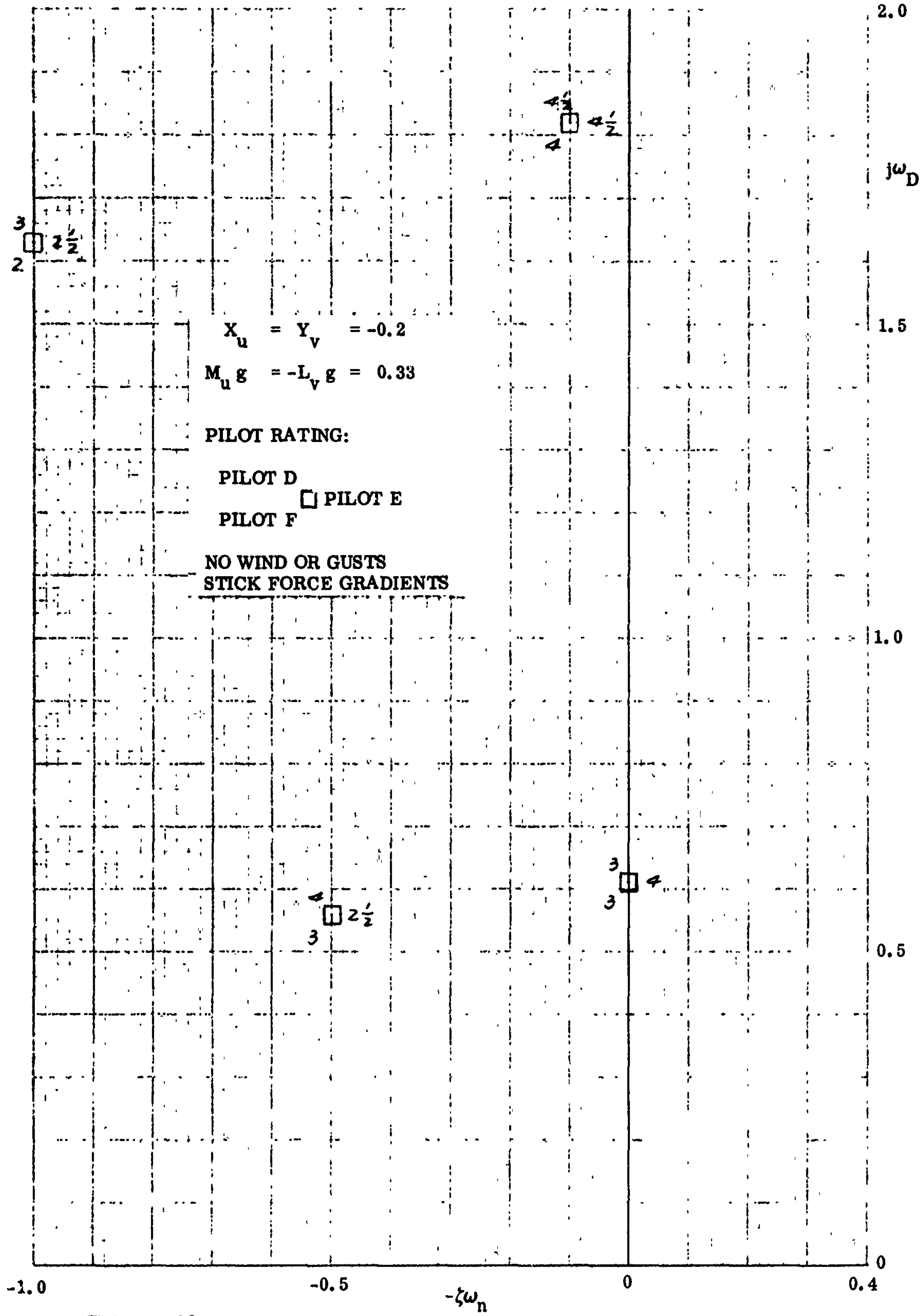


FIGURE 32. PILOT RATINGS FOR THIRD SIMULATION - CASES 342-345

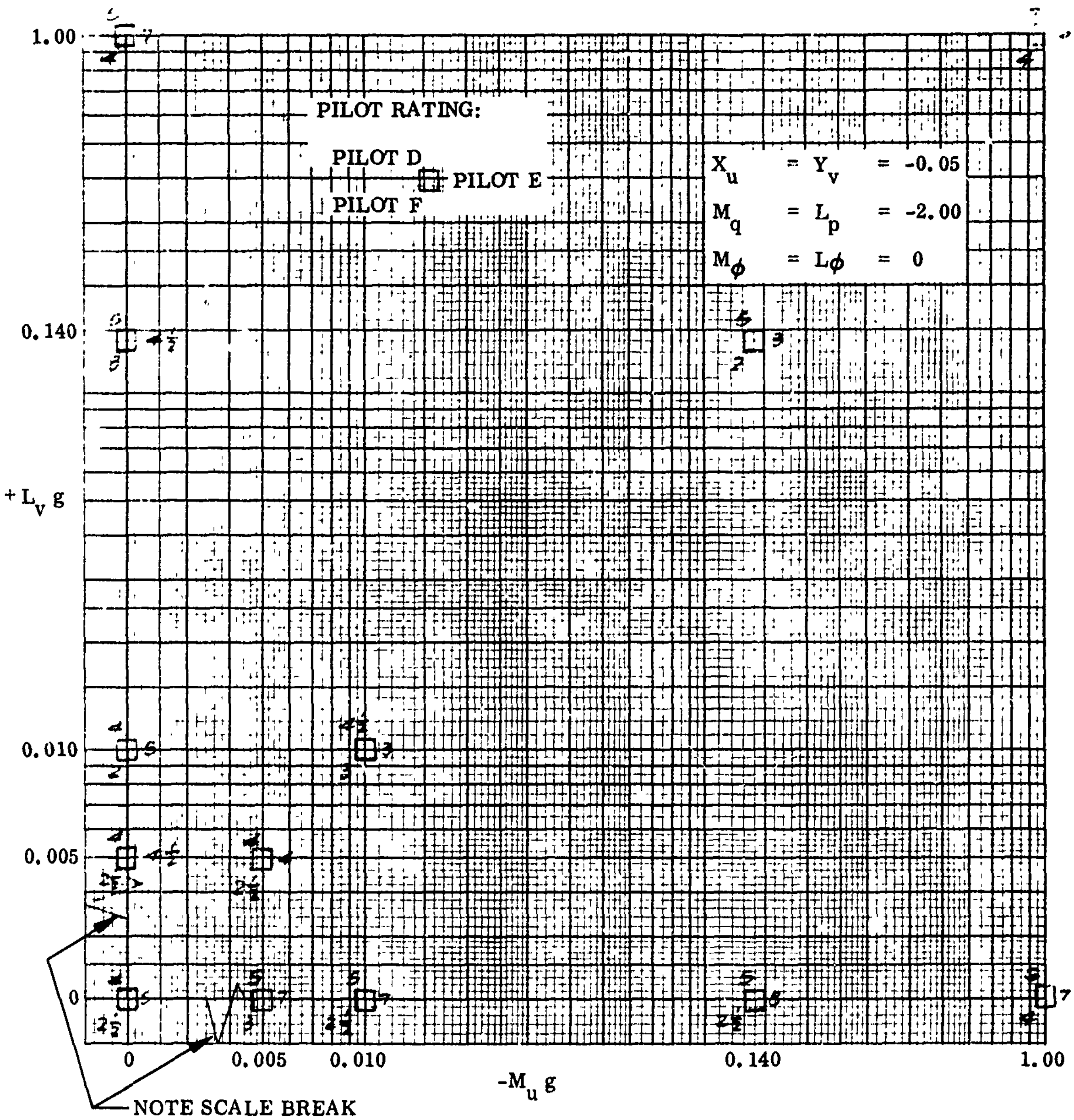


FIGURE 33. PILOT RATINGS FOR THIRD SIMULATION - CASES 321-333

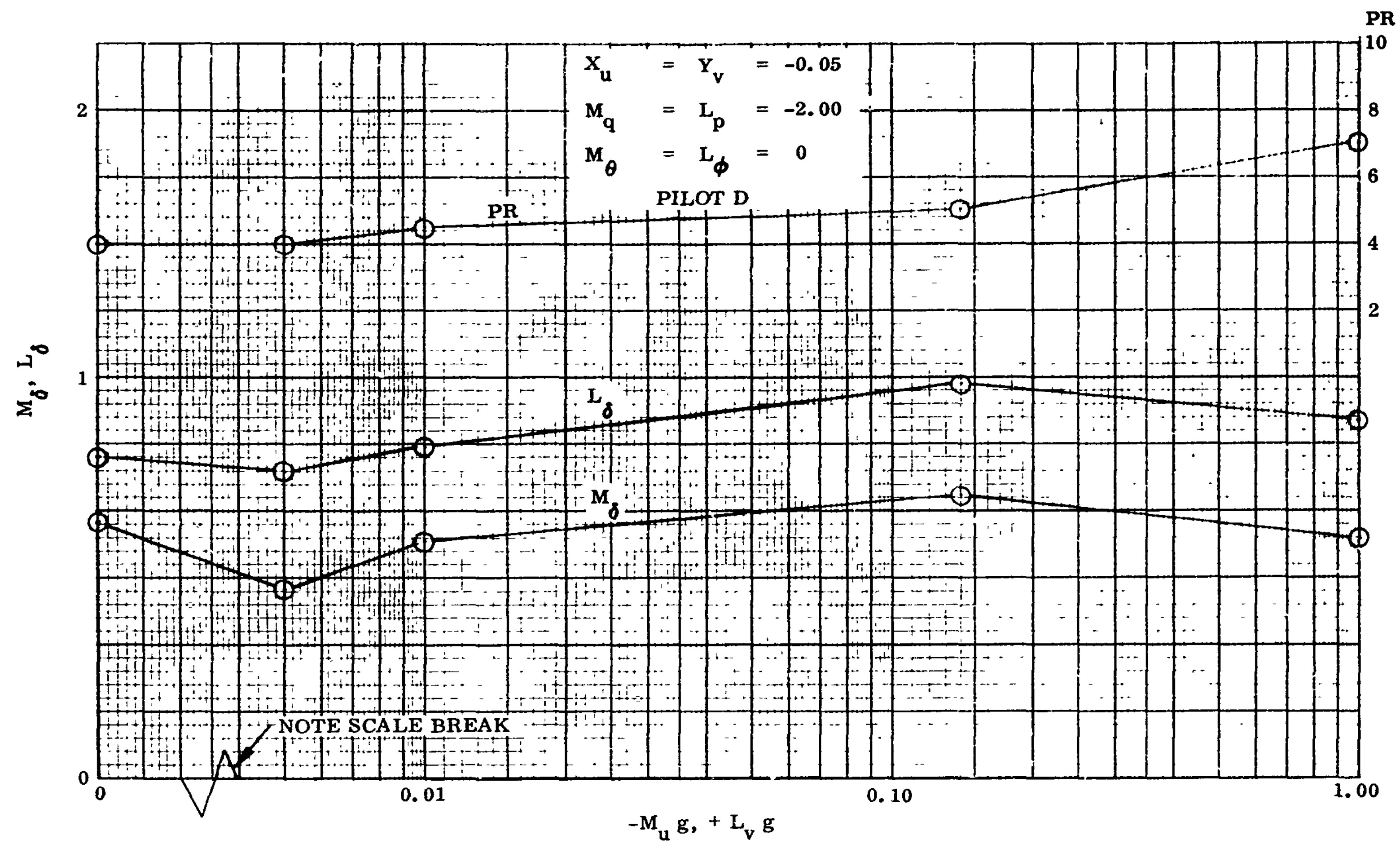


FIGURE 34. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT D FOR THIRD SIMULATION - CASES 321-325

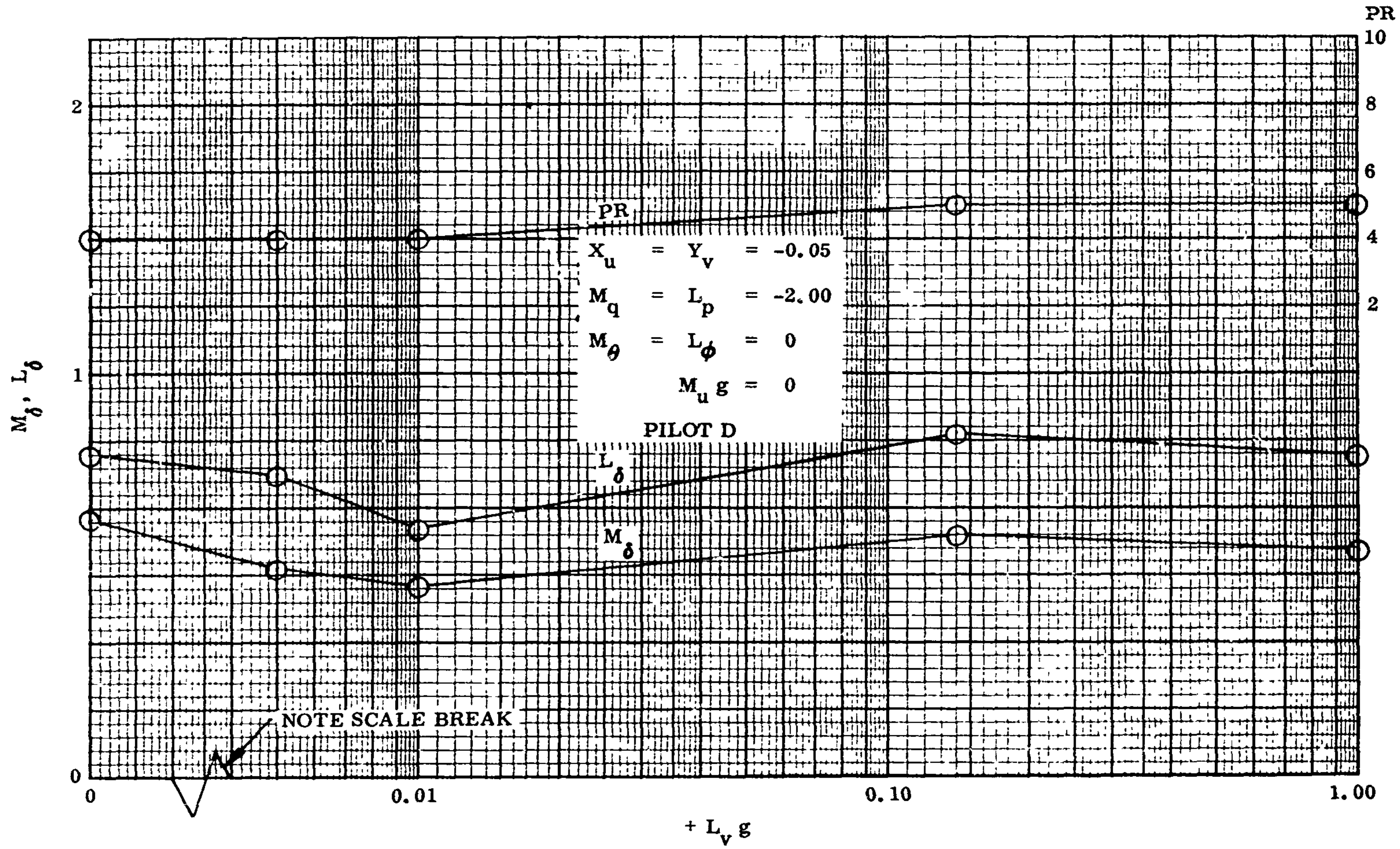


FIGURE 35. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT D FOR THIRD SIMULATION - CASES 326-329 AND 321

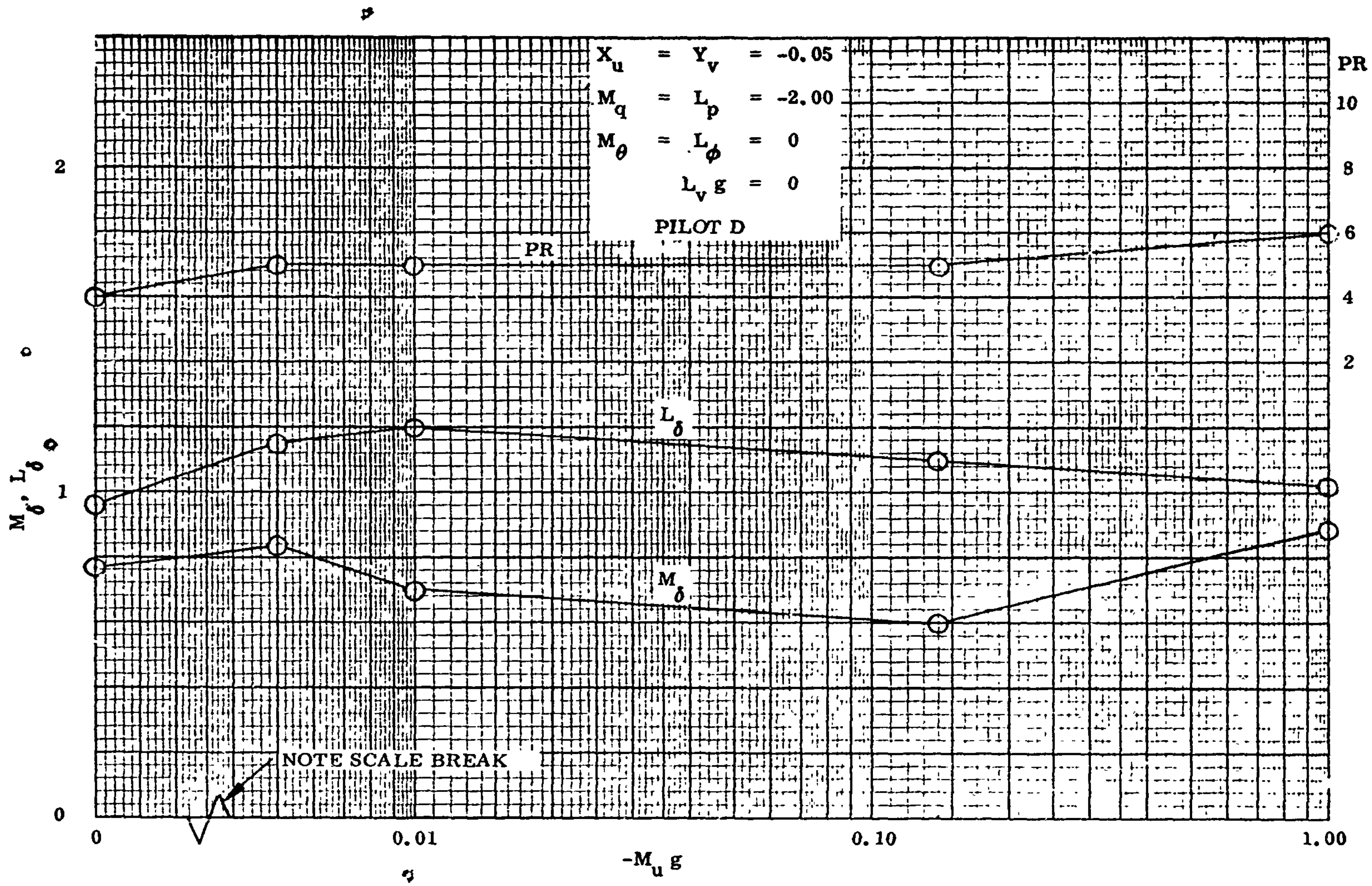


FIGURE 36. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT D FOR THIRD SIMULATION - CASES 330-333 AND 321

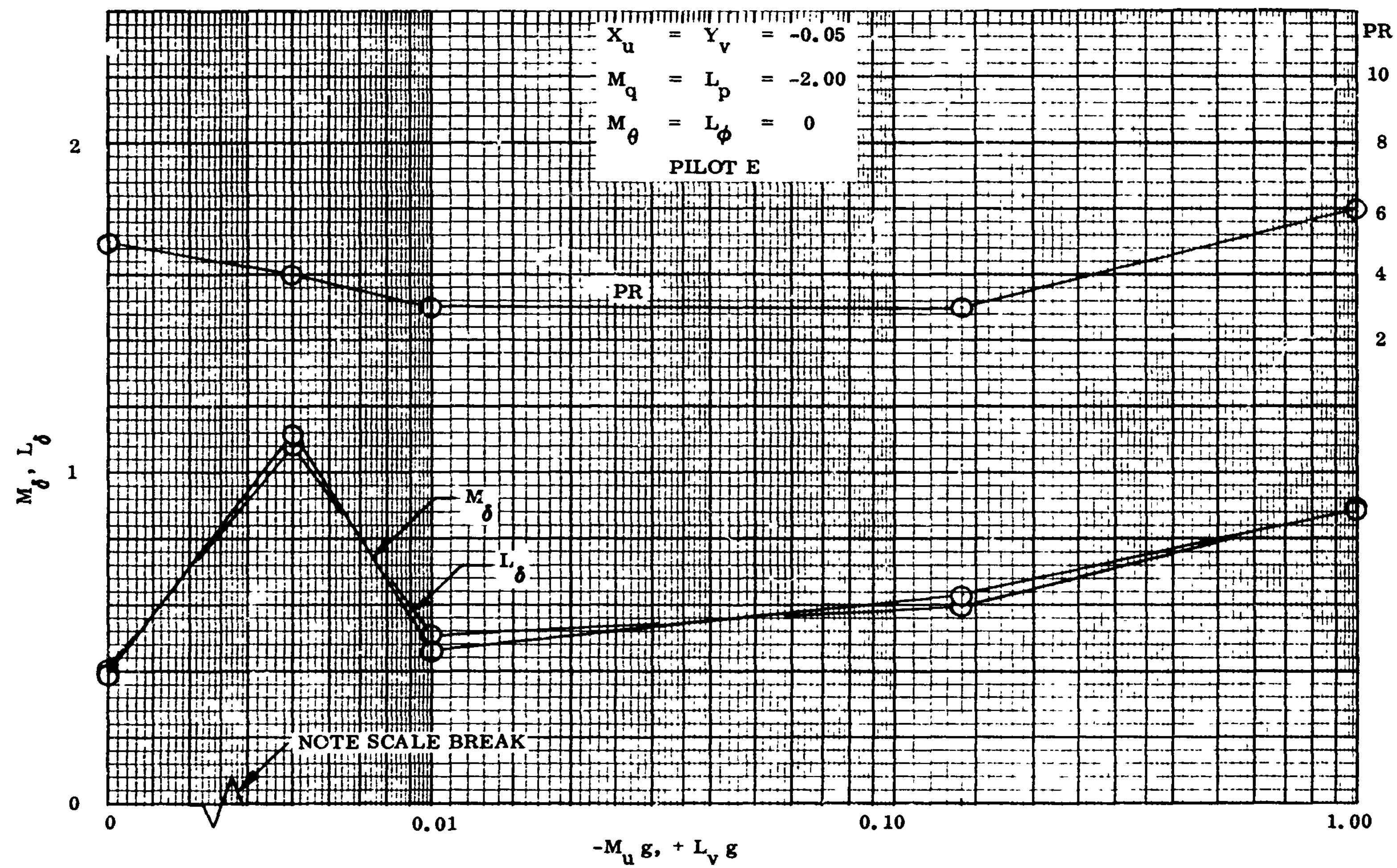


FIGURE 37. PILOT RA.:NGS AND CONTROL SENSITIVITIES SELECTED BY PILOT E FOR THIRD SIMULATION - CASES 321-325

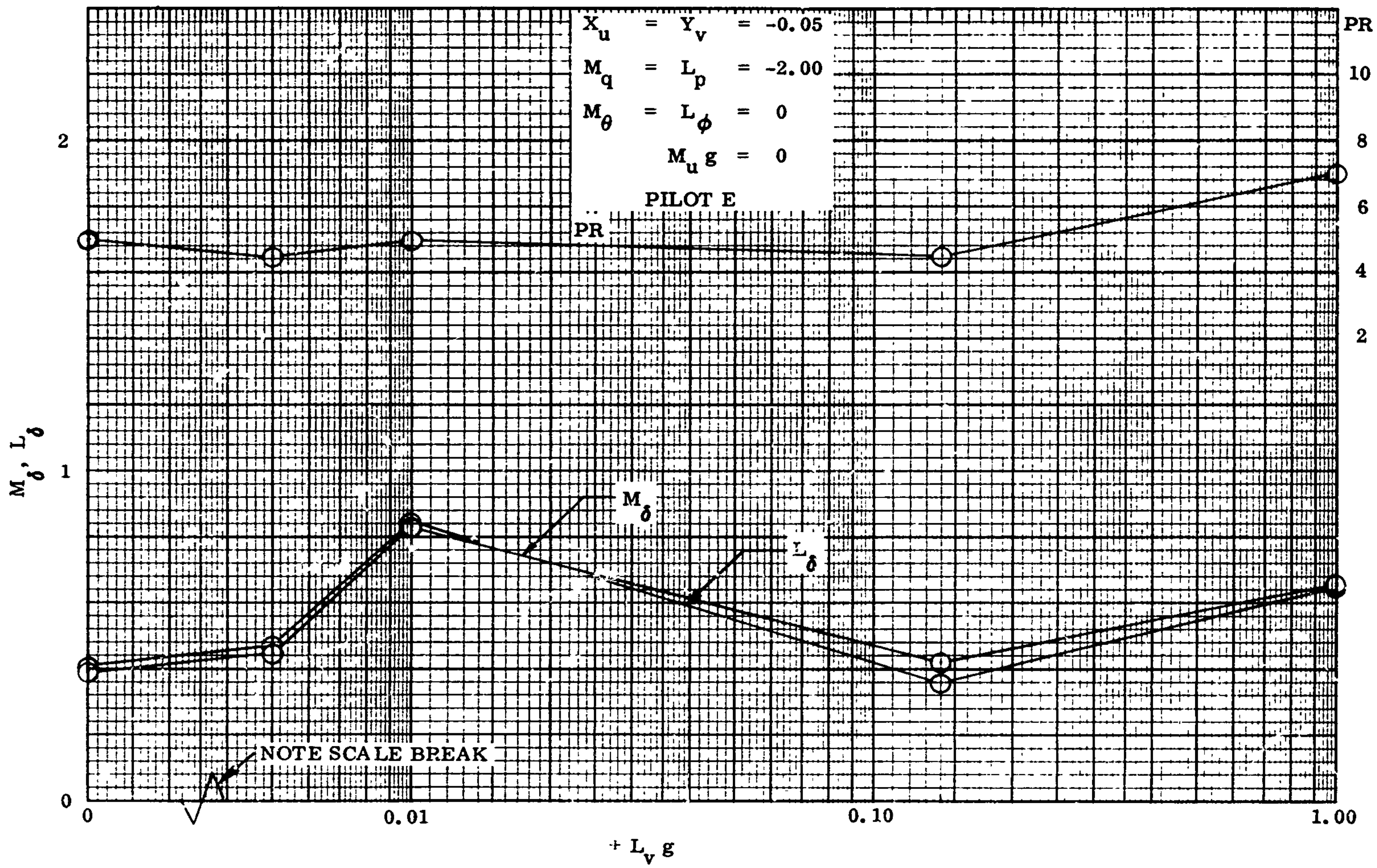


FIGURE 38. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT E FOR THIRD SIMULATION - CASES 326-329 AND 321

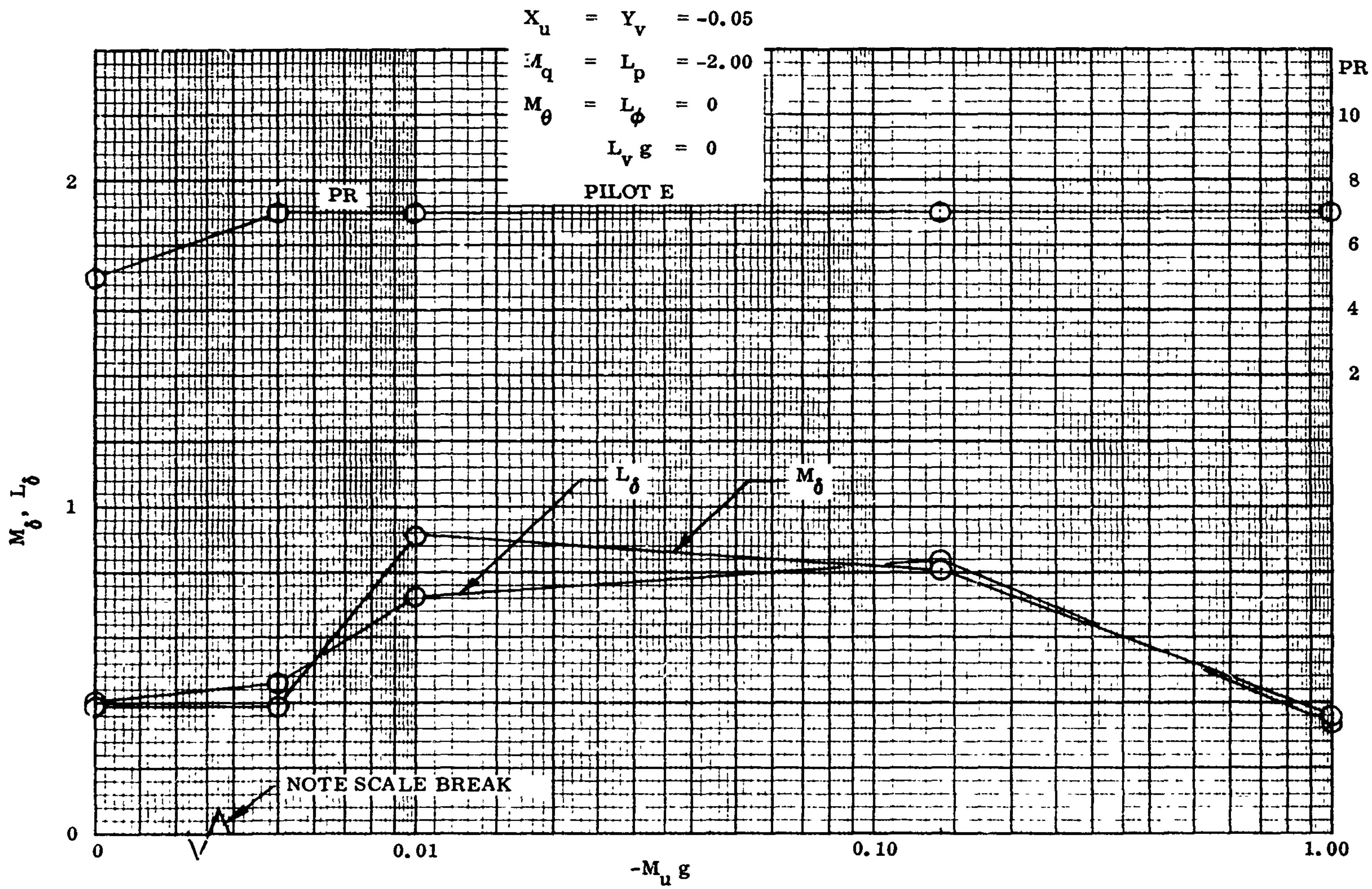


FIGURE 39. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT E FOR THIRD SIMULATION - CASES 330-333 AND 321

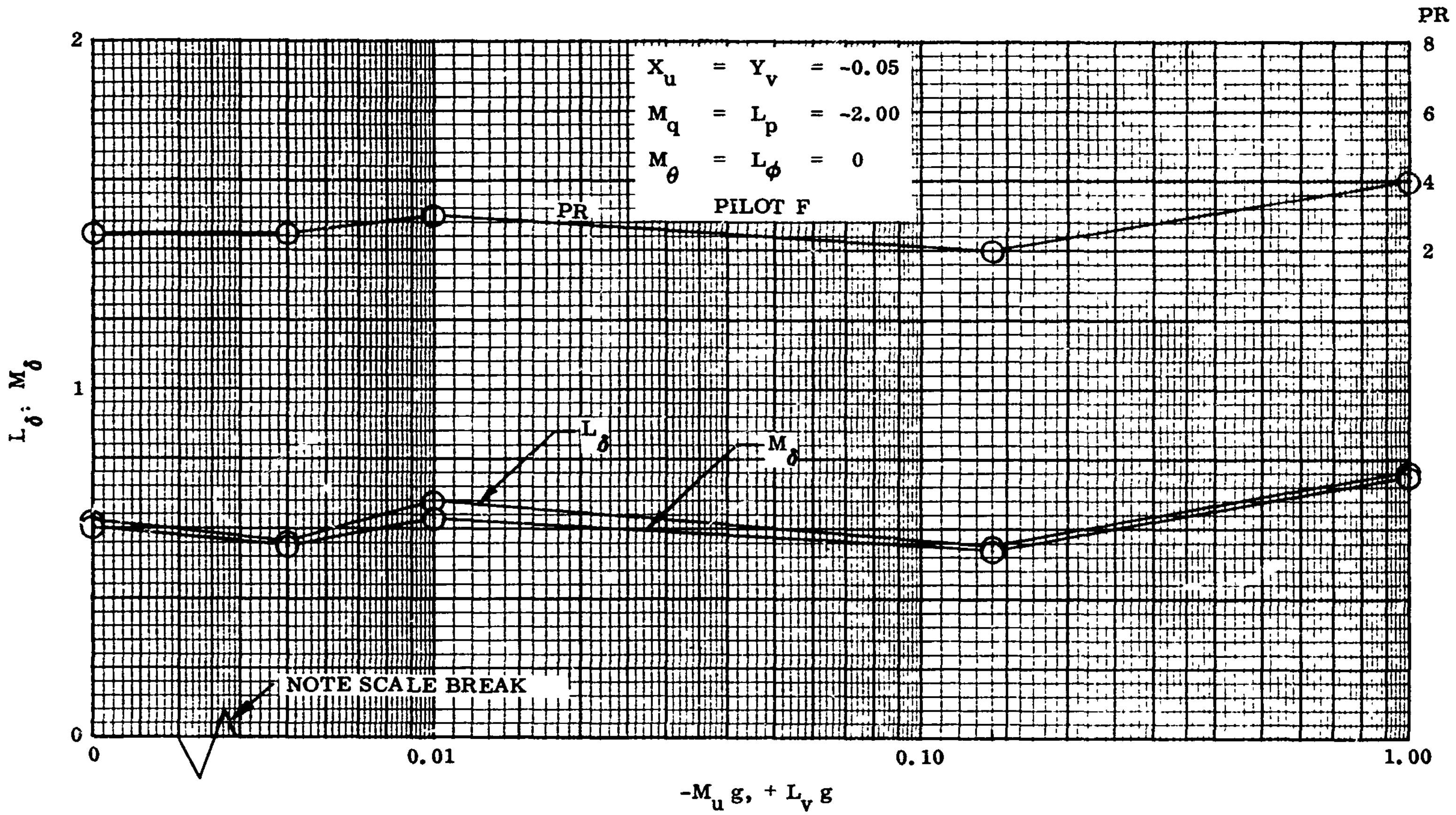


FIGURE 40. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT F FOR THIRD SIMULATION - CASES 321-325

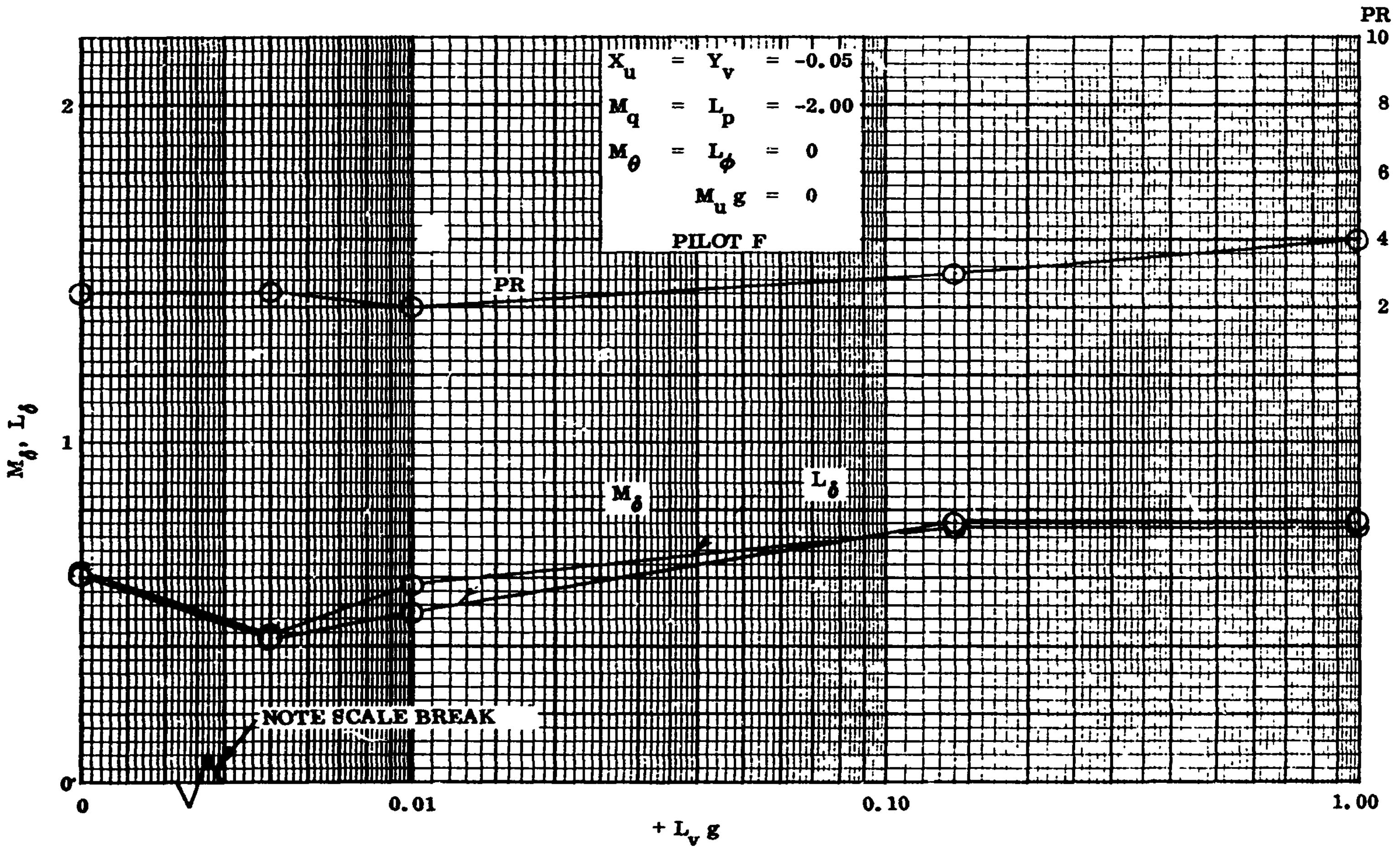


FIGURE 41. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT F FOR THIRD SIMULATION - CASES 326-329 AND 321

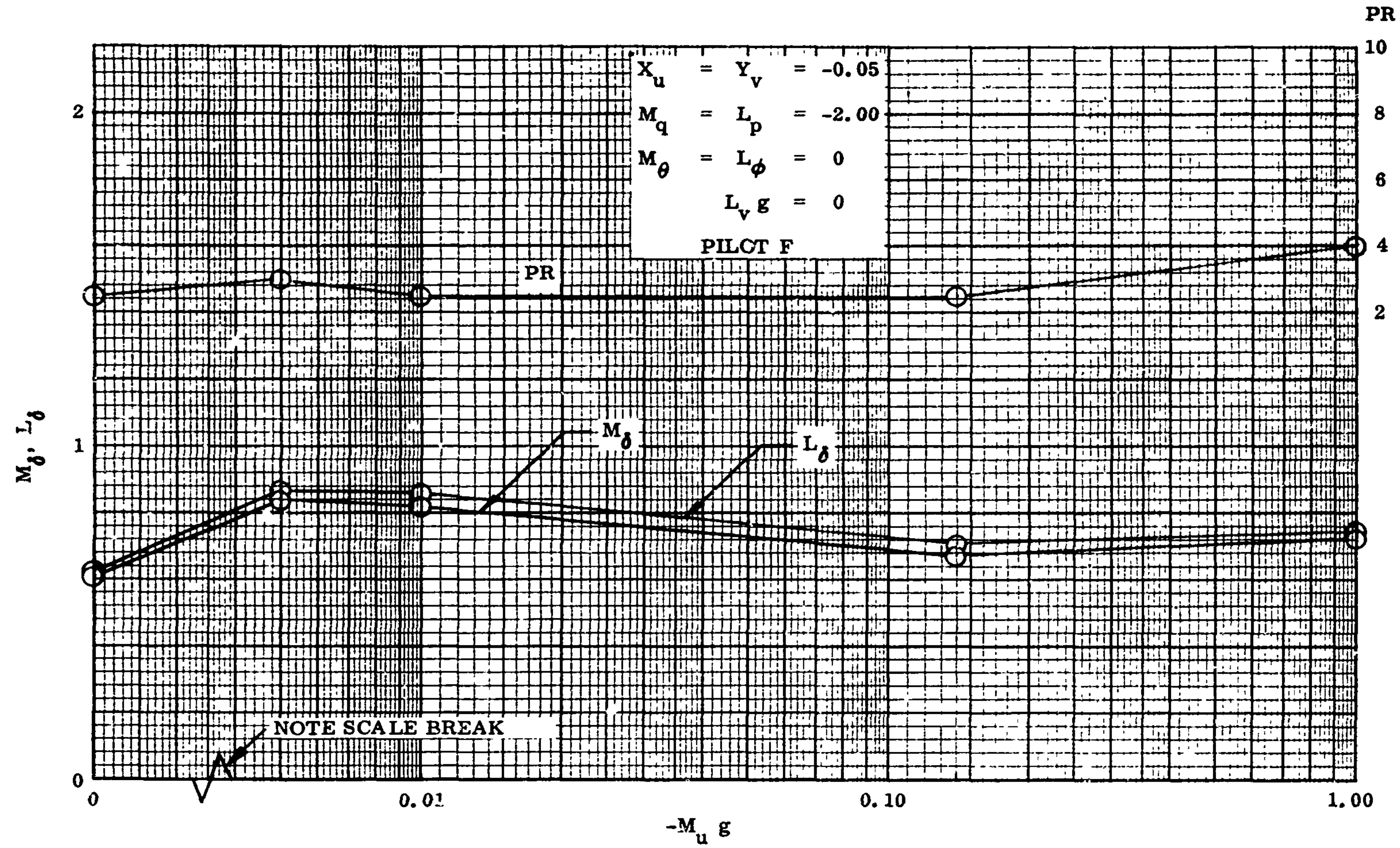


FIGURE 42. PILOT RATINGS AND CONTROL SENSITIVITIES SELECTED BY PILOT F FOR THIRD SIMULATION - CASES 330-333 AND 321

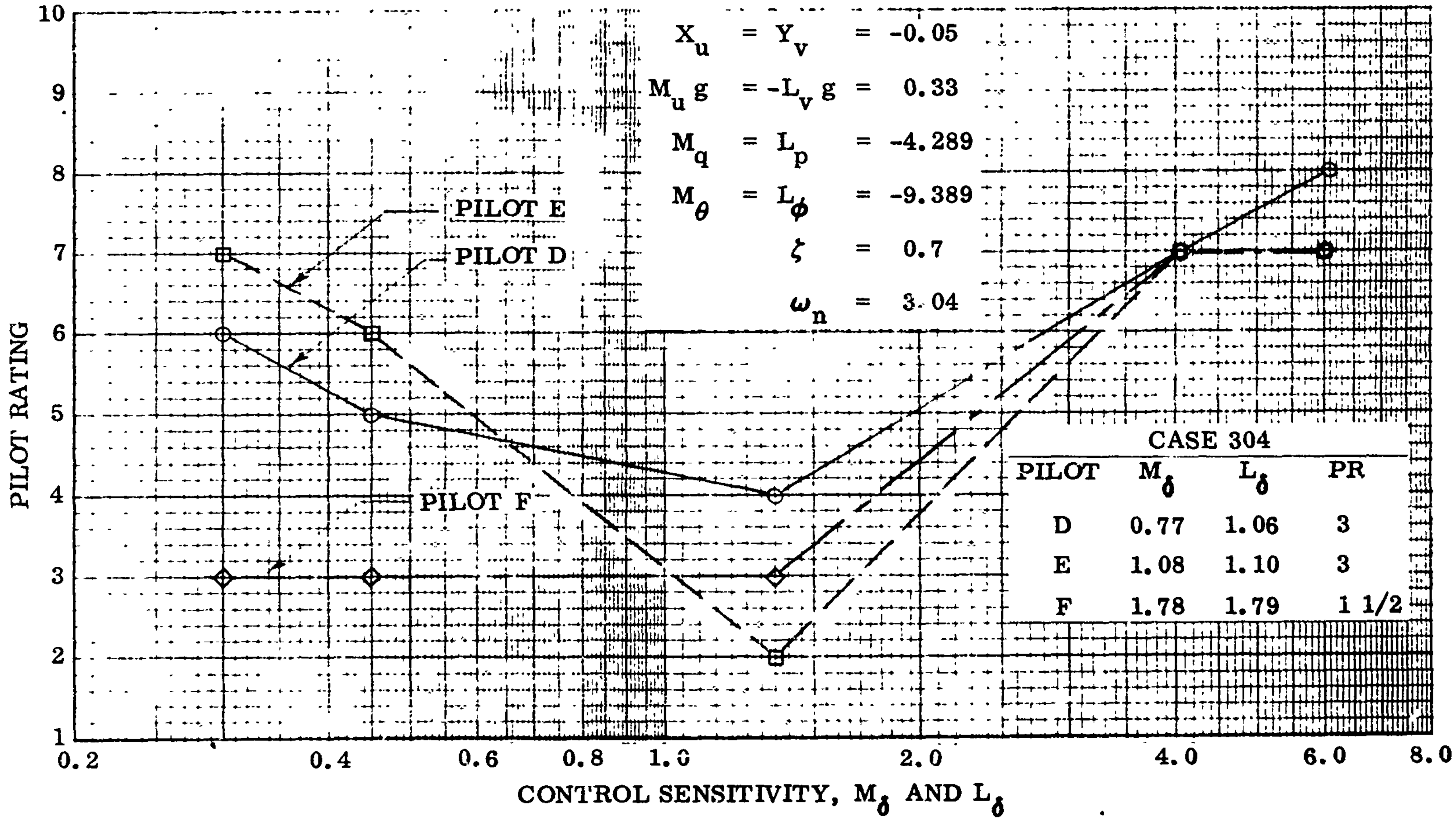


FIGURE 43. PILOT RATINGS FOR THIRD SIMULATION - CASES 346-350

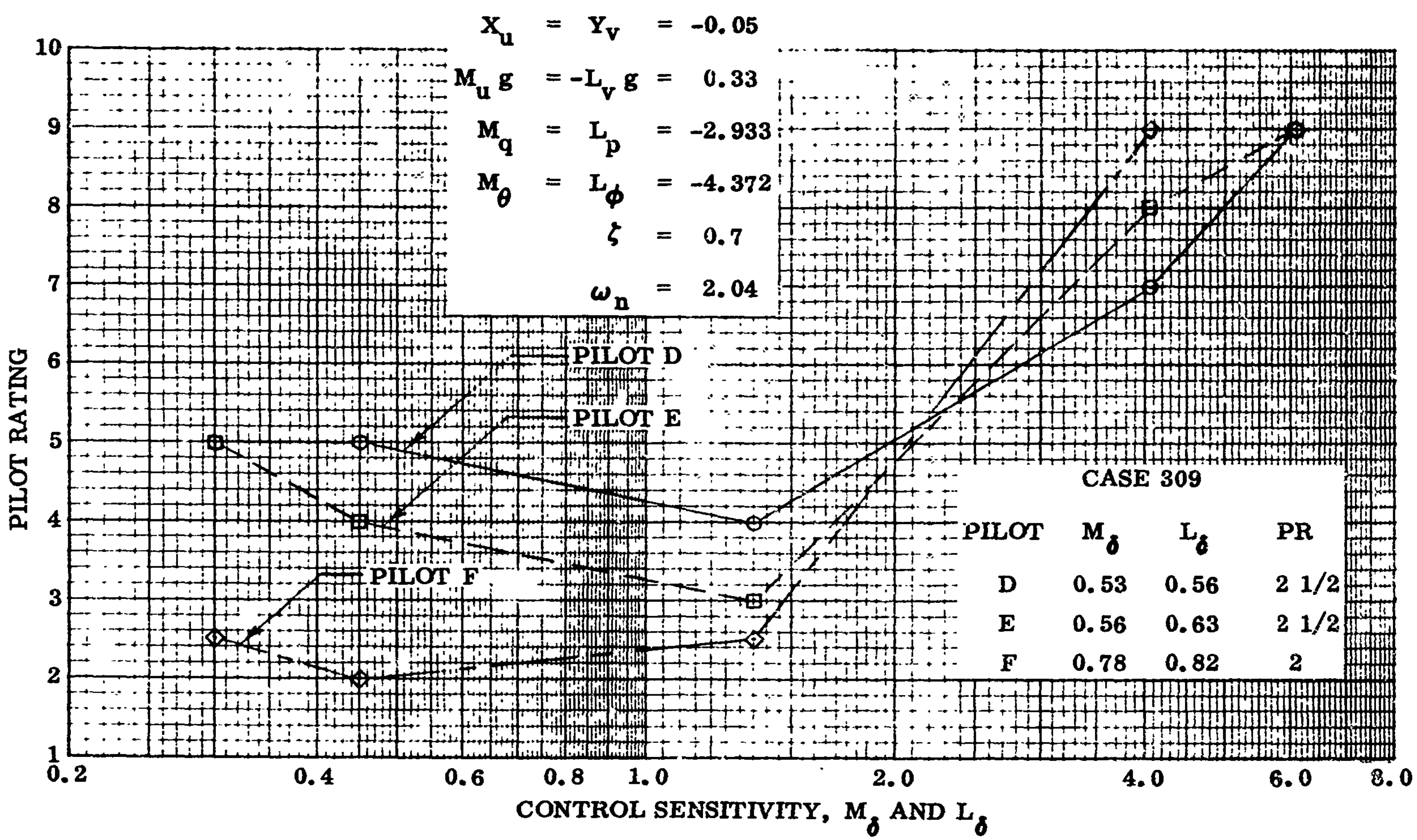


FIGURE 44. PILOT RATINGS FOR THIRD SIMULATION - CASES 351-355

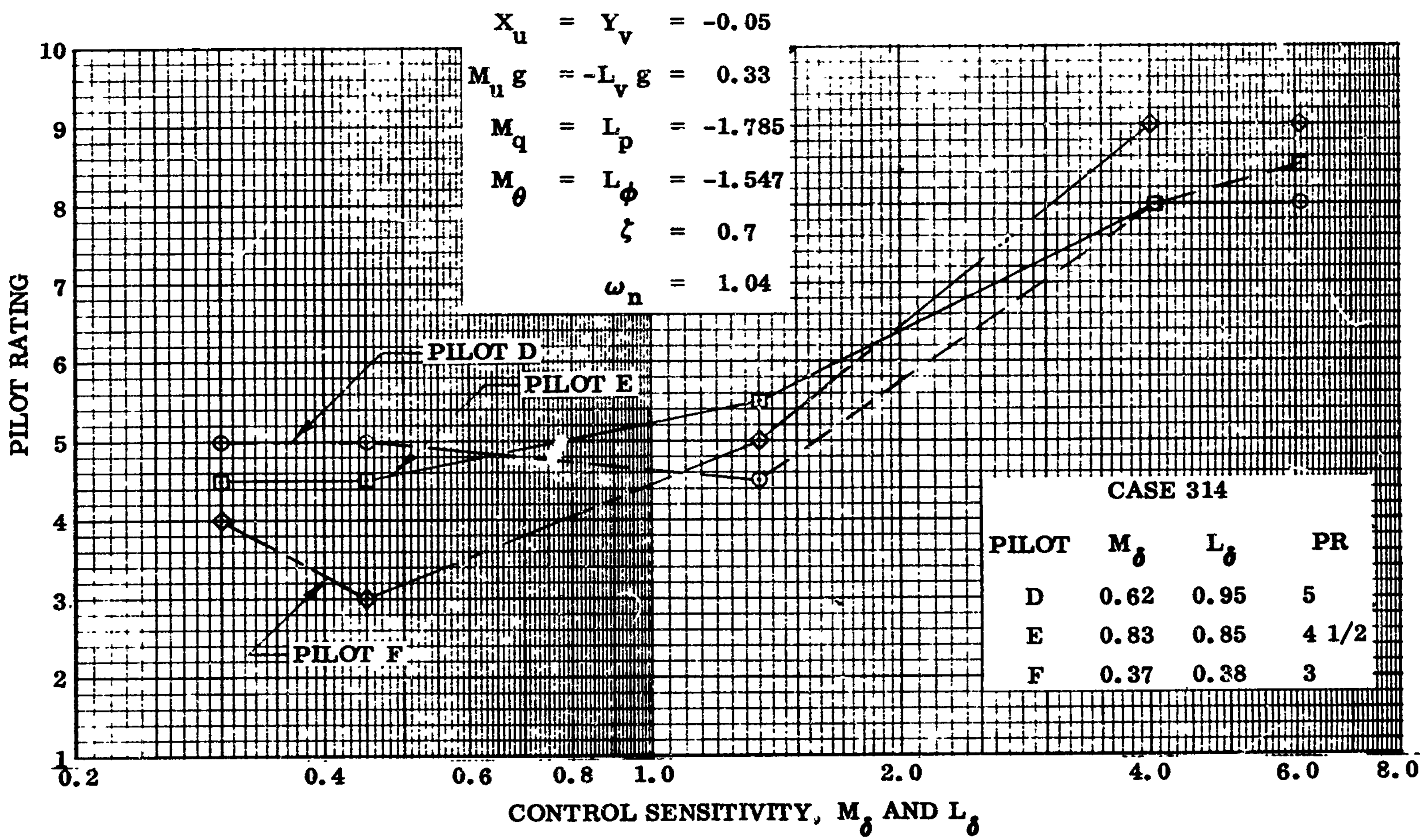


FIGURE 45. PILOT RATINGS FOR THIRD SIMULATION - CASES 356-360

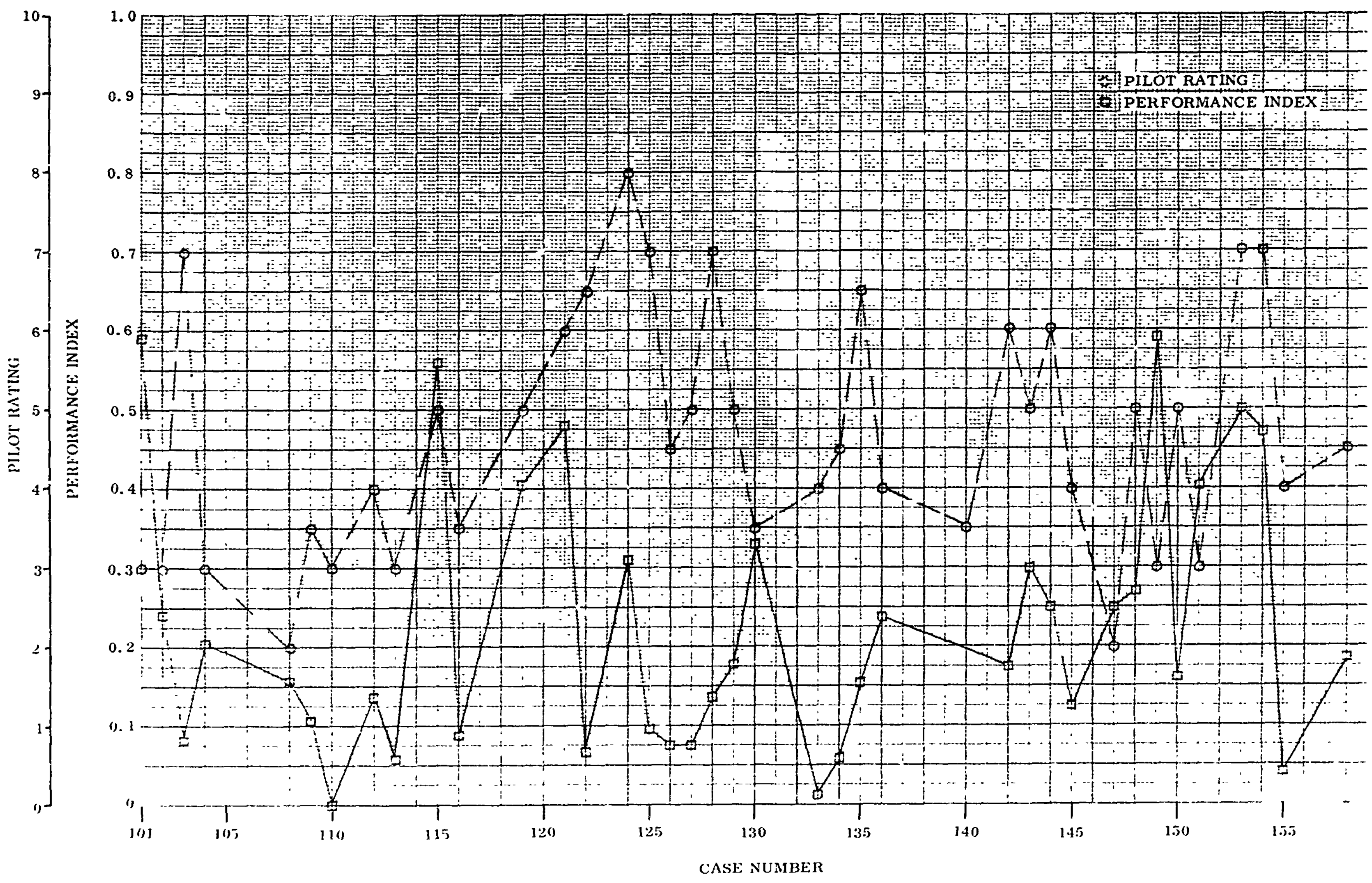


FIGURE 46. PILOT A TRACKING PERFORMANCE

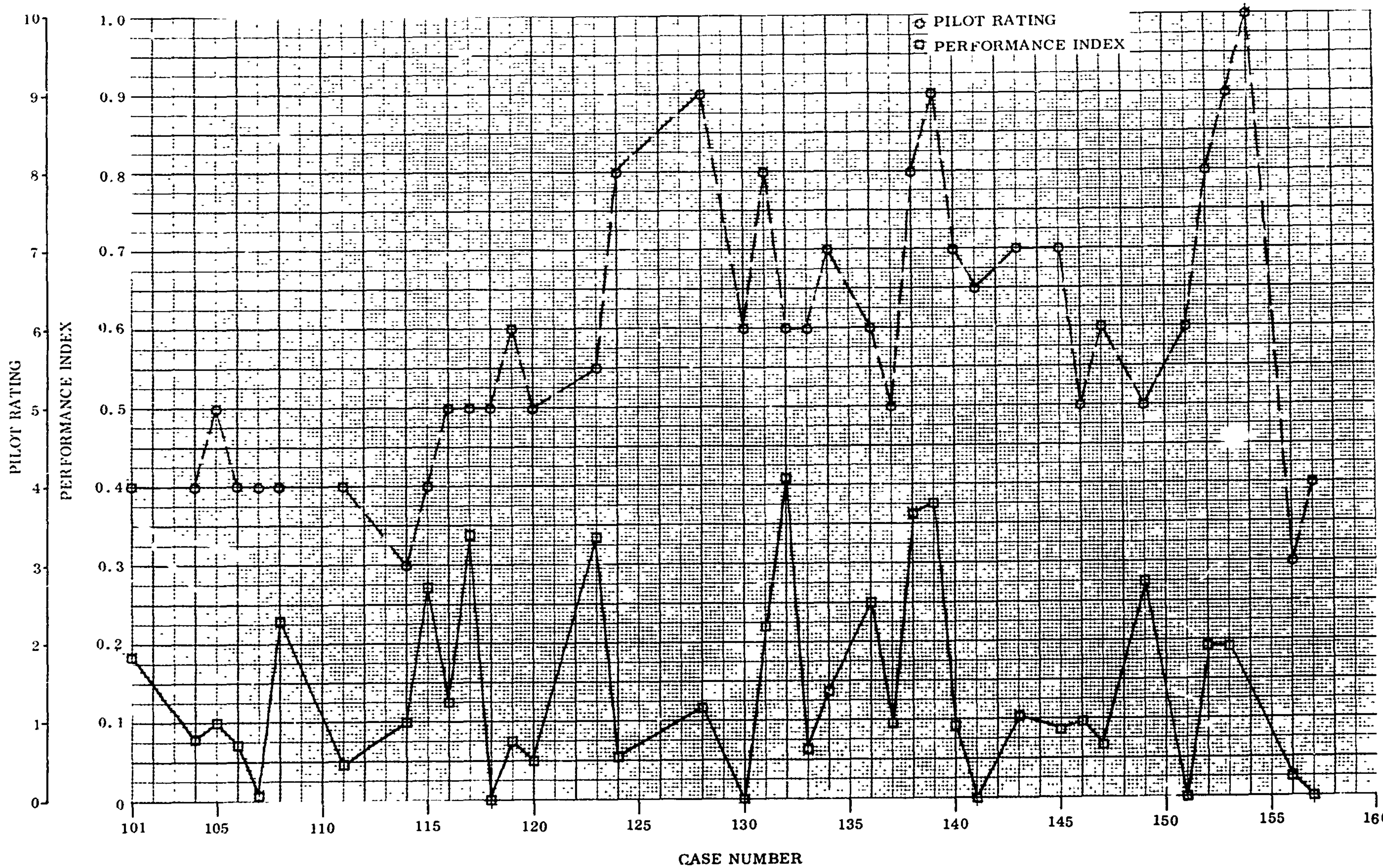


FIGURE 47. PILOT B TRACKING PERFORMANCE

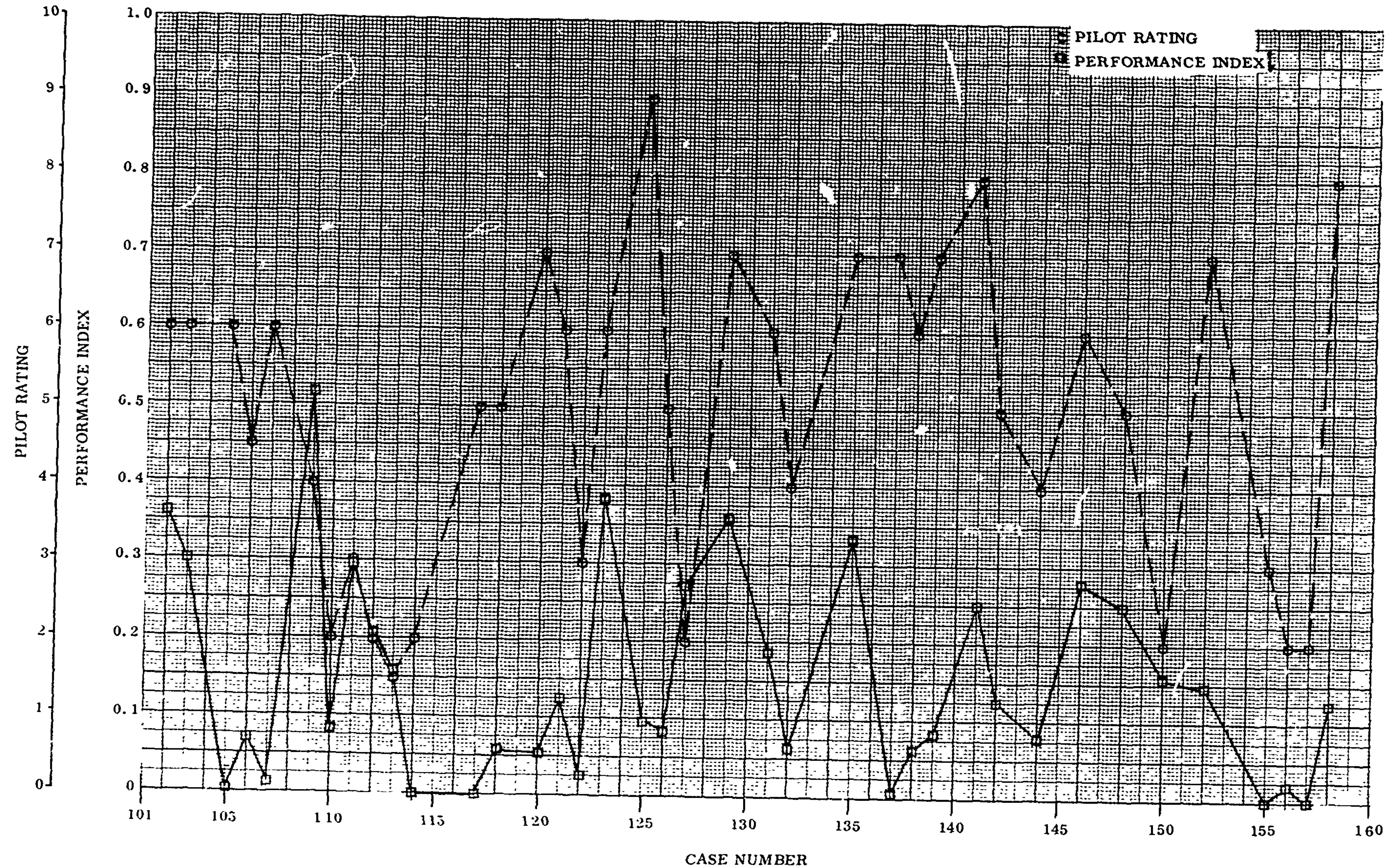


FIGURE 48. PILOT C TRACKING PERFORMANCE

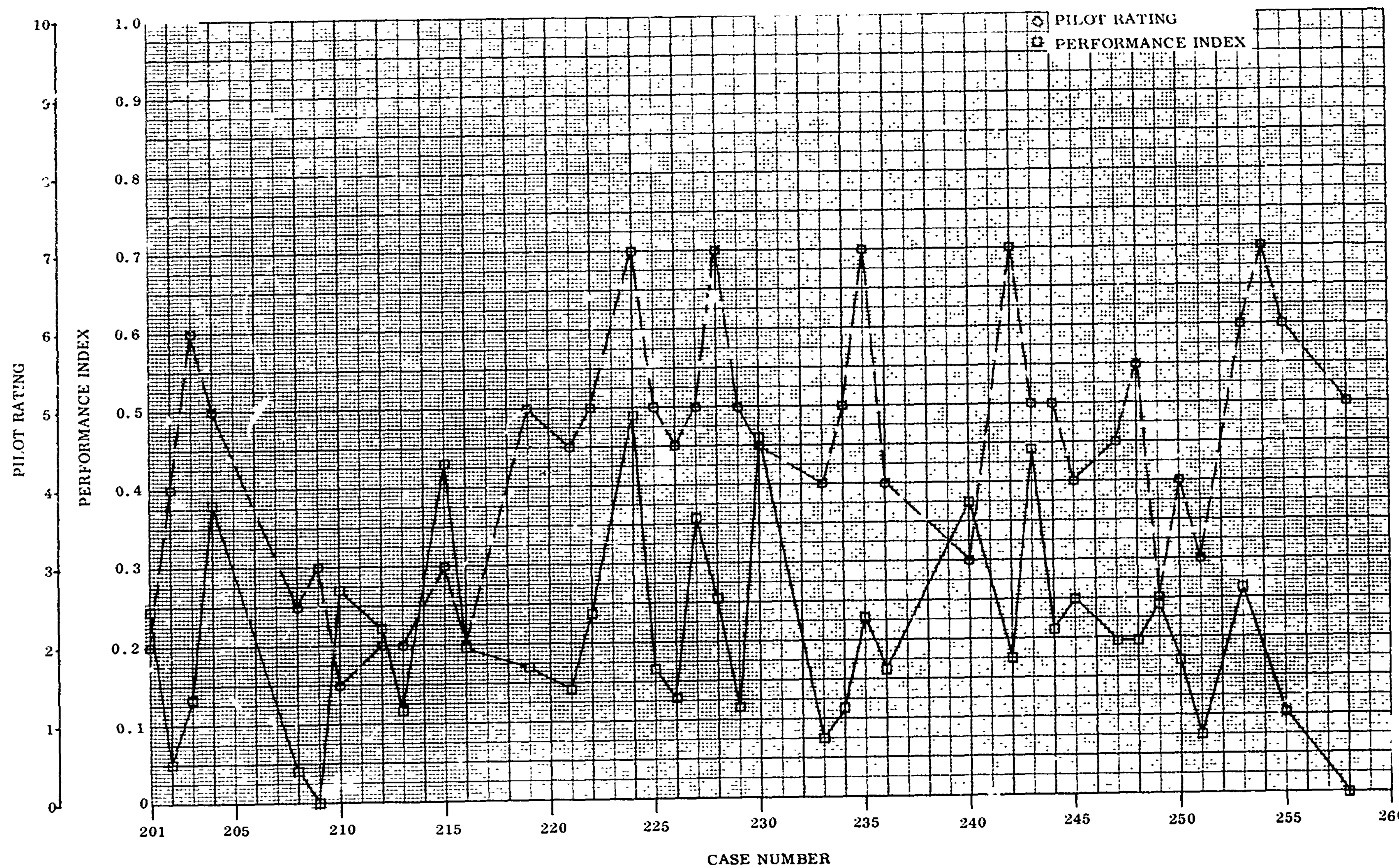


FIGURE 49. PILOT A TRACKING PERFORMANCE

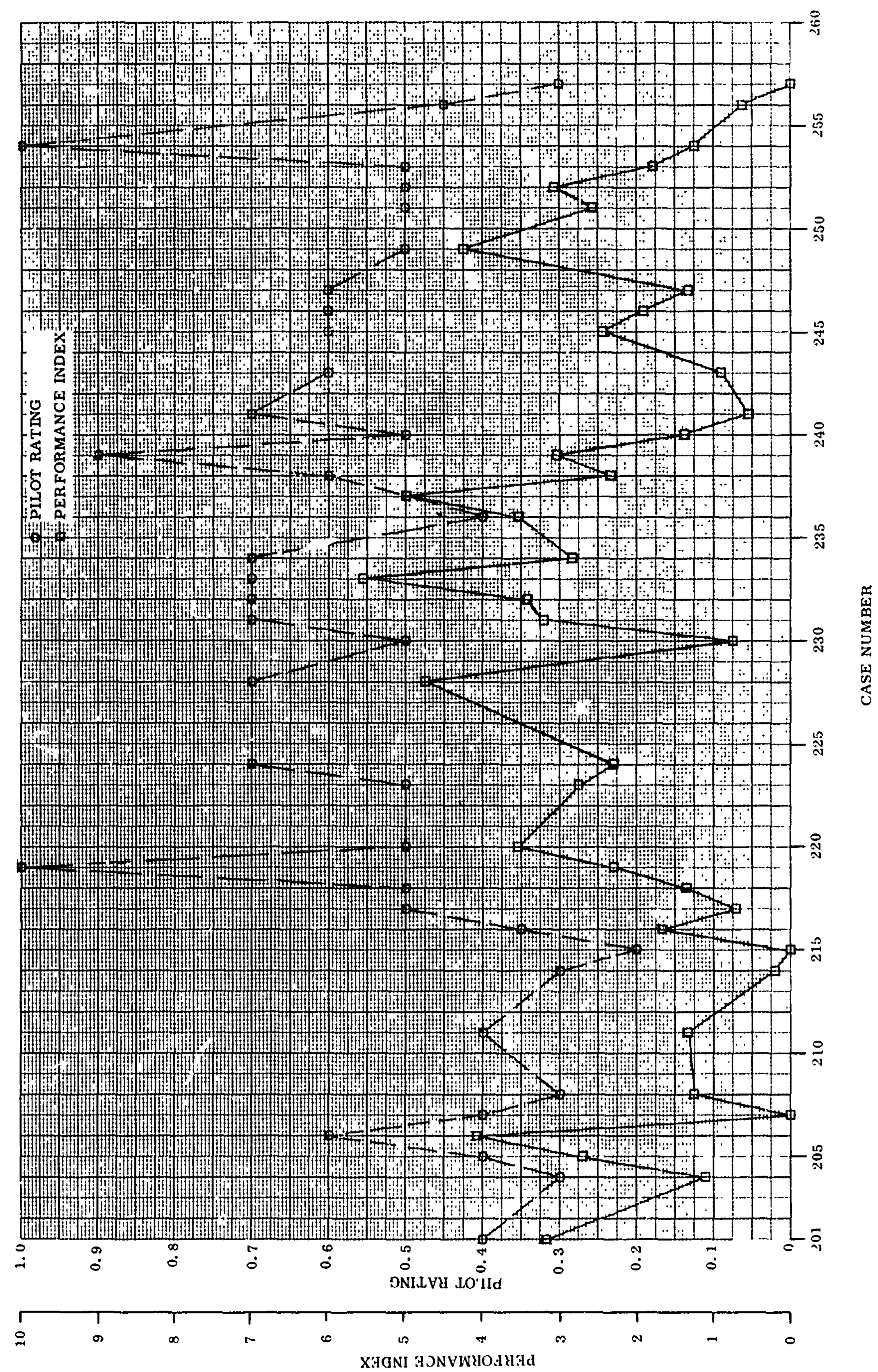


FIGURE 50. PILOT B TRACKING PERFORMANCE

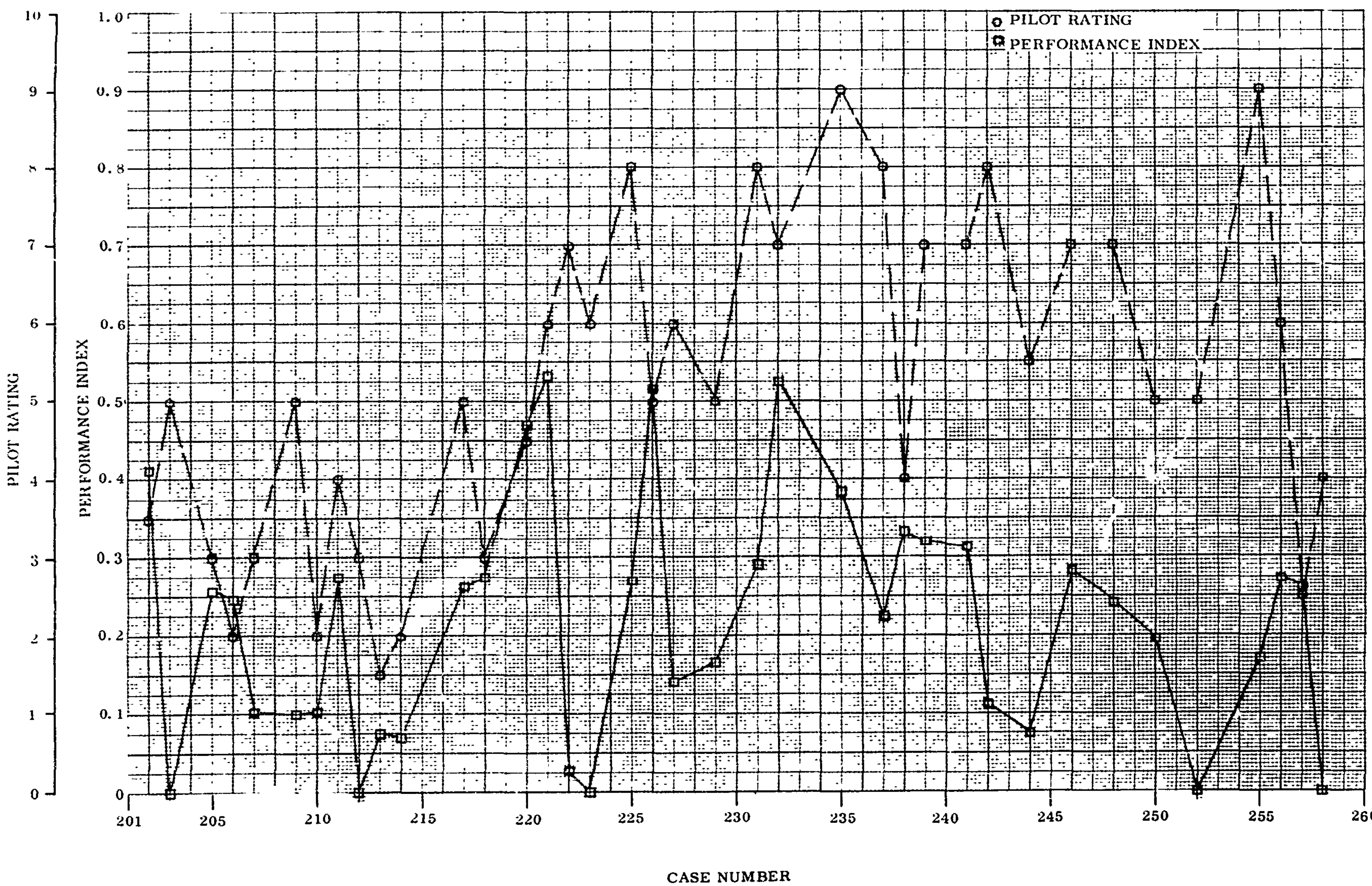


FIGURE 51. PILOT C TRACKING PERFORMANCE

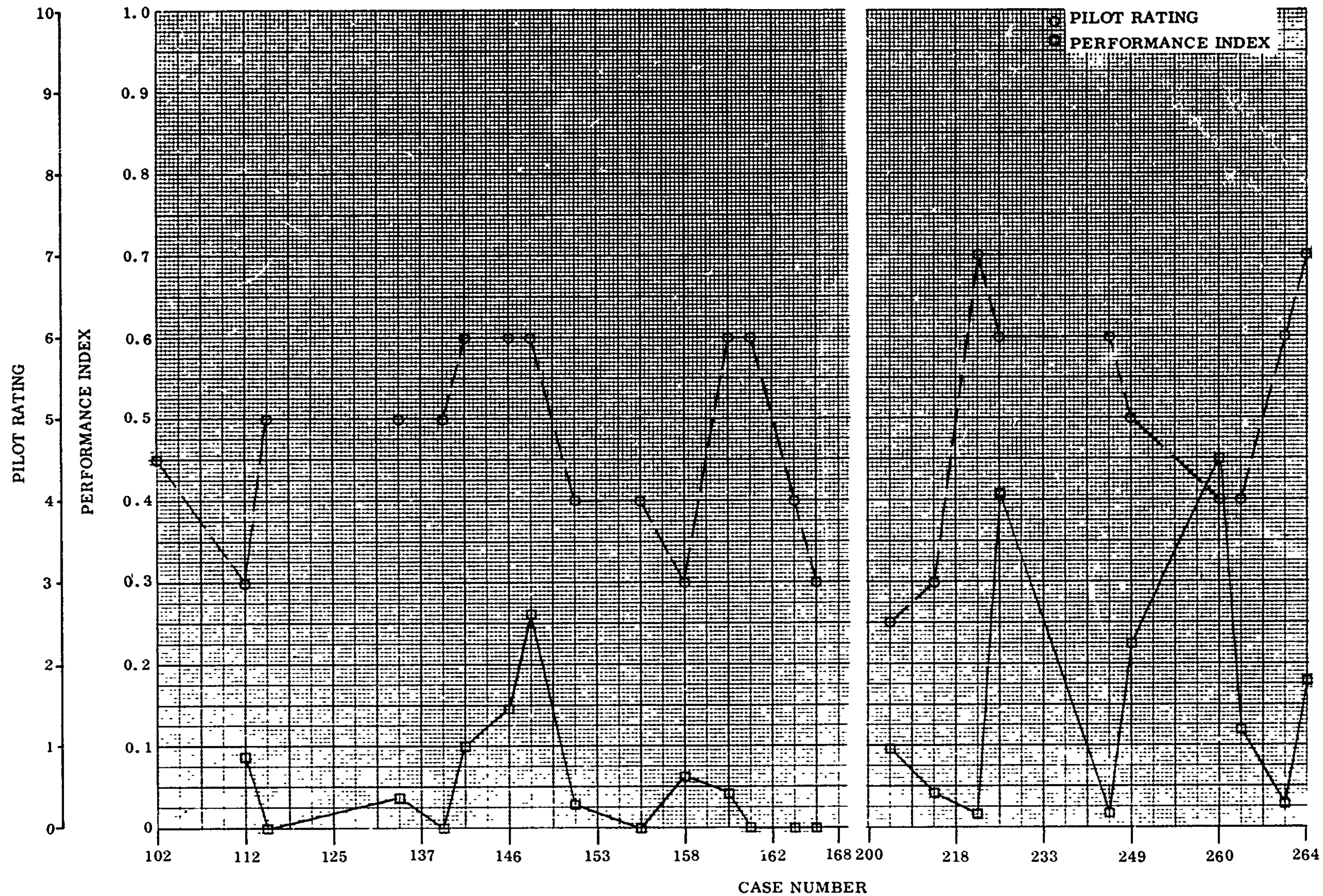


FIGURE 52. PILOT A TRACKING PERFORMANCE

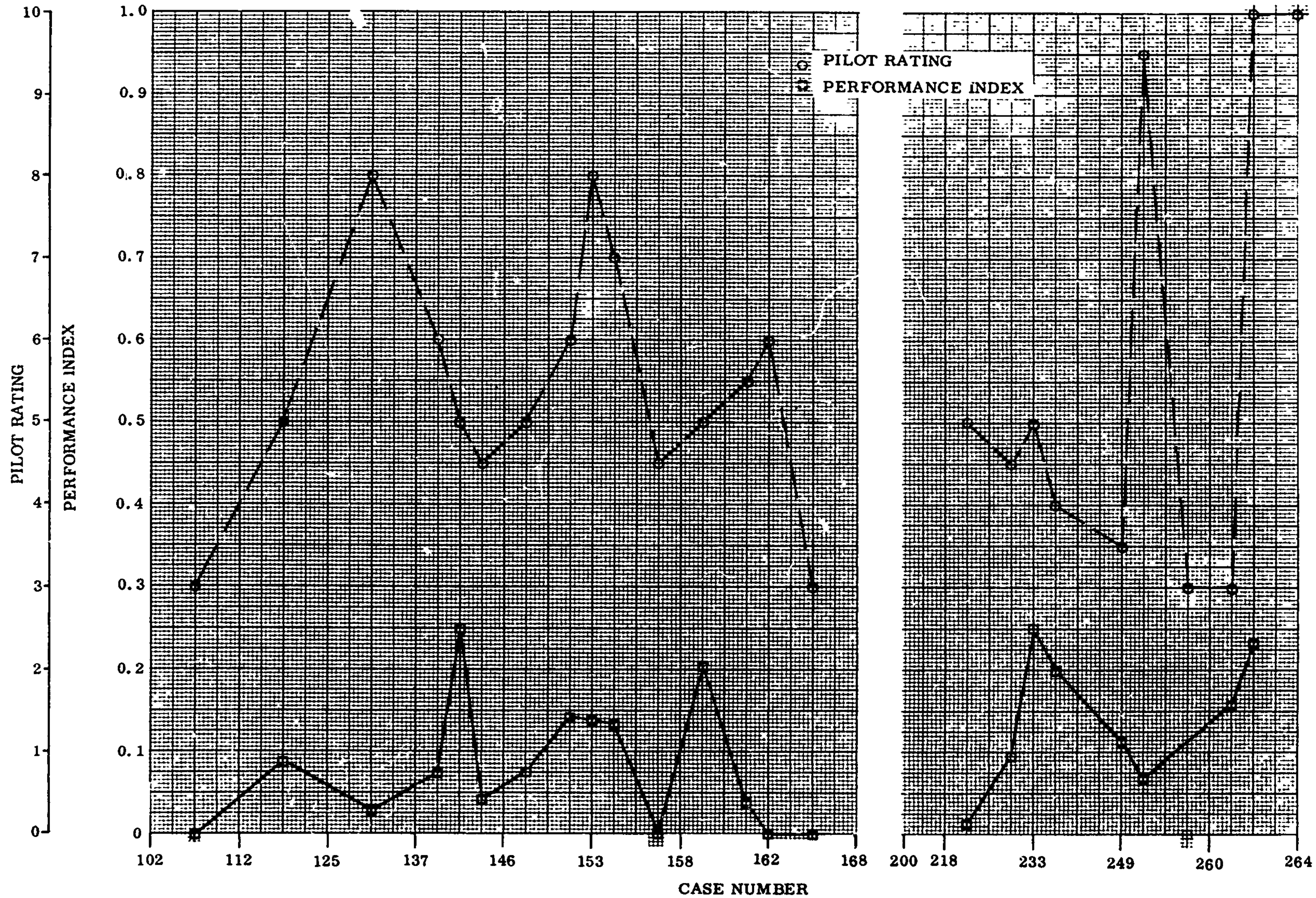


FIGURE 53. PILOT B TRACKING PERFORMANCE

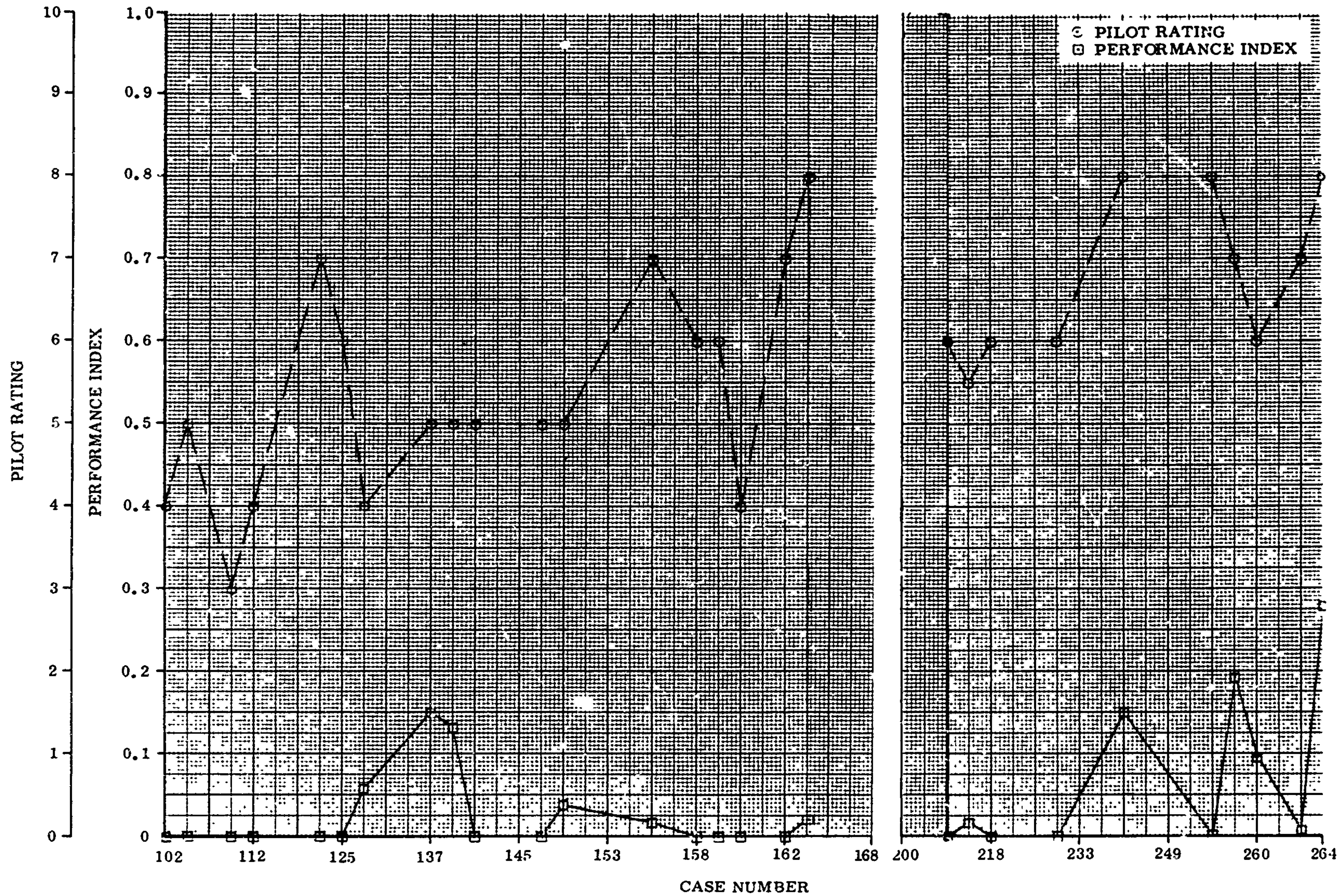


FIGURE 54. PILOT C TRACKING PERFORMANCE

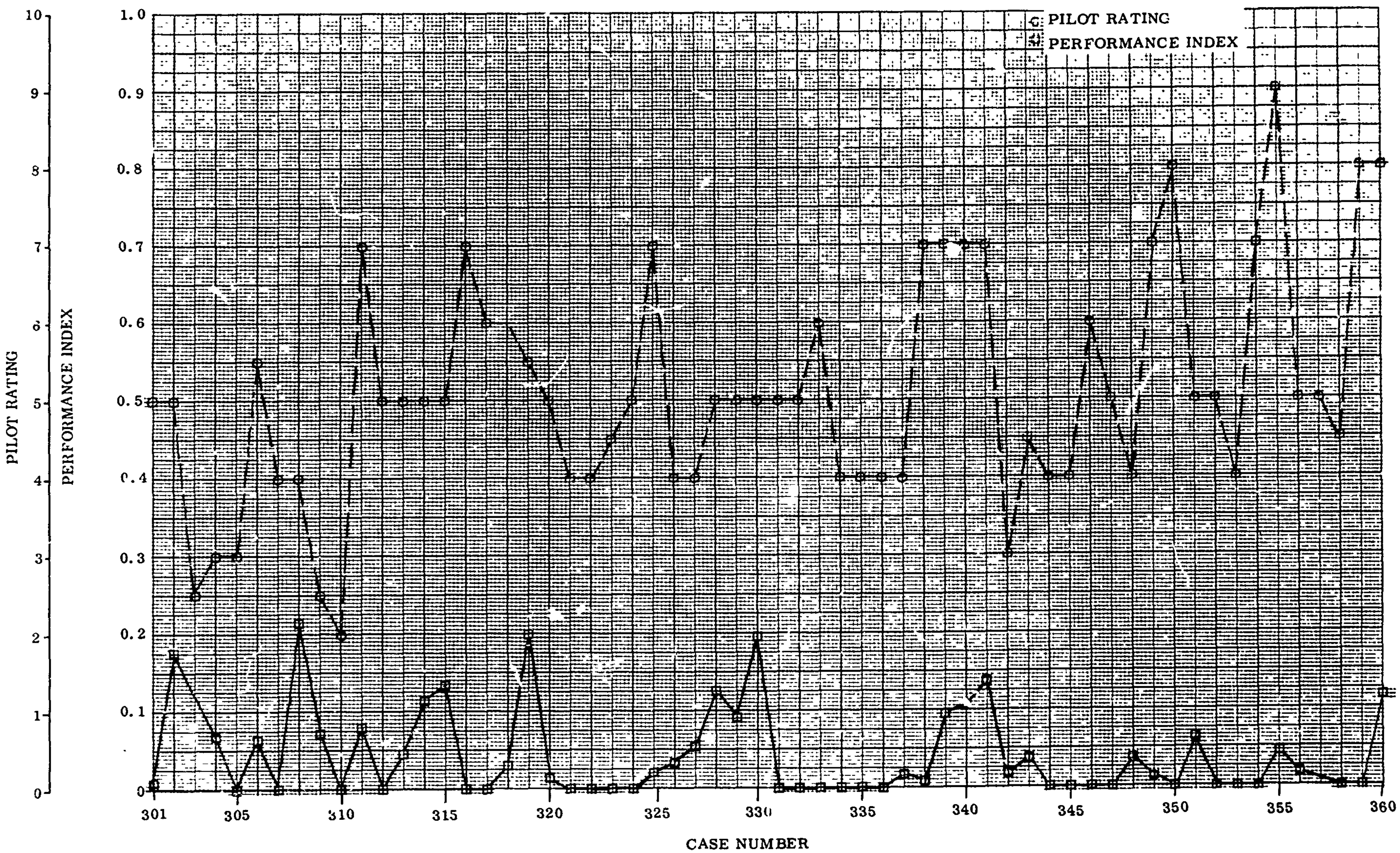


FIGURE 55. PILOT D TRACKING PERFORMANCE

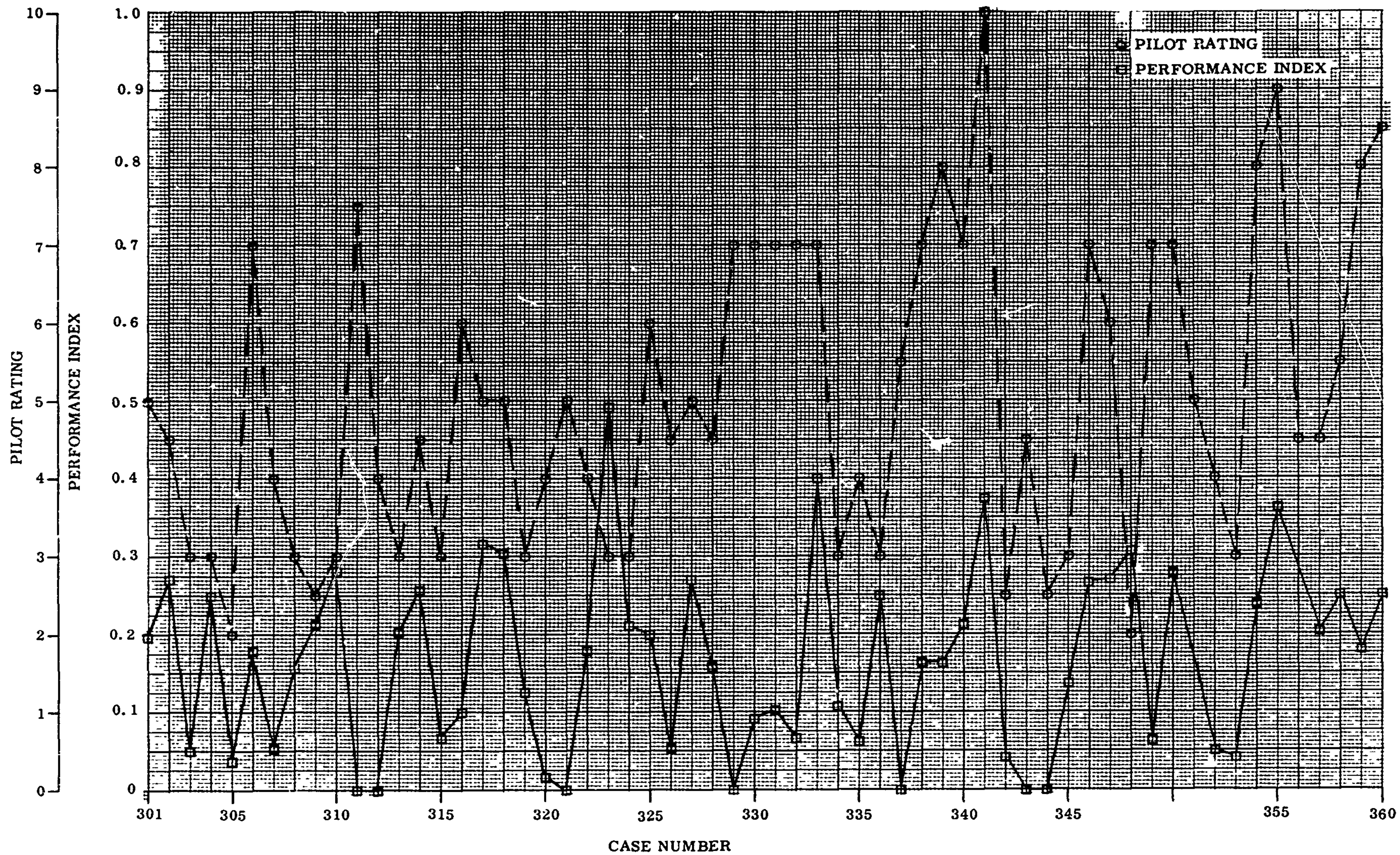


FIGURE 56. PILOT E TRACKING PERFORMANCE

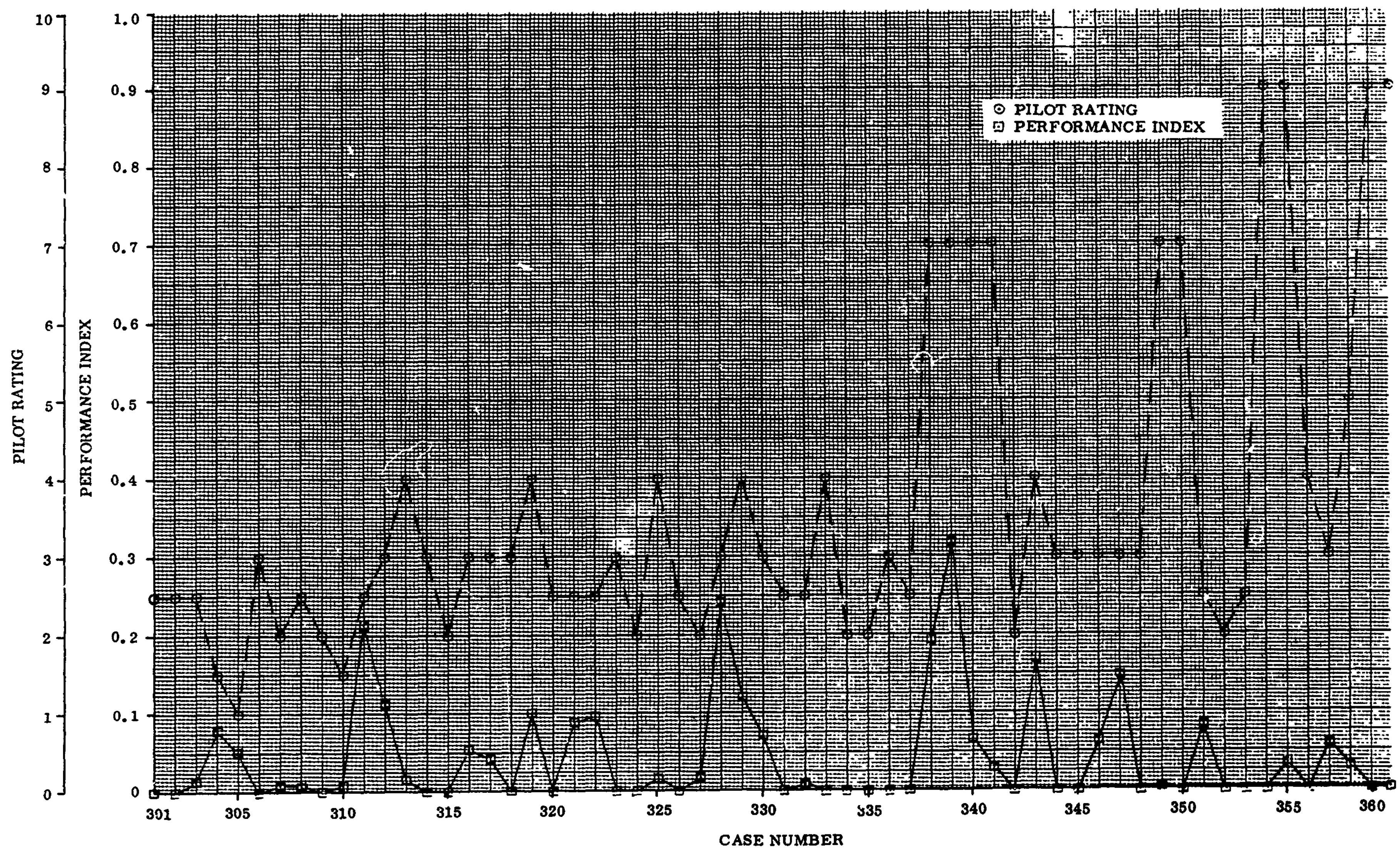


FIGURE 57. PILOT F TRACKING PERFORMANCE

SECTION VII
DISCUSSION

EFFECT OF DRAG FACTORS X_u AND Y_v ON PILOT RATING

In the first and second simulations, the longitudinal handling qualities parameters were varied while the lateral and directional parameters were held at "good" levels; then the lateral parameters were varied while the longitudinal and directional parameters were held at "good" levels. In the third simulation, the lateral and longitudinal dynamics were identical and varied identically for all cases except 326 through 333.

The most significant parameters affecting pilot appreciation of airplane dynamics were X_u and Y_v. Comparison of data in Figures 21 and 25 shows the degradation of pilot rating as X_u is changed from -0.05 to -0.2. A similar comparison of data in Figures 22 and 26 also shows the degrading influence of the drag factors. Since the speed stability was held constant, the degradation of handling qualities that occurred was not because of speed stability.

A survey of the pilot comments indicates that the objections arise because of the large attitude changes required to compensate for wind effects and the large attitude changes required to initiate motion or to maneuver.

EFFECT OF SPEED STABILITY PARAMETERS M_u AND L_v ON PILOT RATING

Due to the overpowering influence of the drag factors, no clear and precise observations can be made concerning the effects of the speed stability parameters on the handling qualities.

EFFECT OF STEADY WIND, GUSTS, AND STICK FORCE GRADIENTS

Pilot comments in the first and second simulations indicated that steady winds and gusts had a strong influence on the acceptability of the configurations with high drag factors.

Some of the tests conducted in the third simulation were made to test the influence of steady winds and gusts. Comparison of the data in Figures 31 and 32 shows the degradation of handling qualities with steady winds and gusts.

A few tests to establish the effect of having stick force gradients were made. Comparison of the data in Figures 30 and 32 shows no effect of stick force gradients in the absence of steady winds and gusts.

Cases 334 through 345 are similar to cases run in the first simulation. The dynamics of both the longitudinal and lateral axes of Cases 334, 338, and 342 are the same as the longitudinal dynamics of Case 120 and the lateral dynamics of Case 220. The same relationship exists between Cases 122, 222, 335, 339, and 343; 126, 226, 336, 340, and 344; and 128, 228, 337, 341, and 345. Pilot ratings for all of these cases are compared in Table IX. Cases 334 through 337 were without winds, turbulence, and stick force gradients. Cases 342 through 345 had no winds or turbulence. Cases 338 through 341 had winds, turbulence, and stick force gradients. The 100- and 200-numbered cases had winds and turbulence but no stick force gradients. Also for the 100-numbered cases, the lateral dynamics were set at a standard configuration as were the longitudinal dynamics of the 200-numbered cases. The predominant feature of the ratings in Table IX is the unacceptability of Cases 338 through 341. The existence of stick forces when no wind or turbulence was present did not seem to be important; i.e., the ratings for Cases 334 through 337 were very similar to those for Cases 342 through 345.

VARIATION IN PILOT RATING WITH CONTROL SENSITIVITY

A series of tests was made during the third simulation where longitudinal and lateral control sensitivities were varied at constant airplane dynamic characteristics. The data in Figures 43, 44, and 45 show the strong influence of control sensitivity on pilot rating. These data appear consistent with the sensitivity and pilot rating data obtained in the tests where sensitivities were selected by the pilots. (Cases 304, 309, 314.) Comparison of the data taken during these tests also is shown in Figures 43, 44, and 45. Again, the most significant comment to be made about control sensitivity is that the personal preferences of the individual pilot cause large variations in preferred sensitivity for a particular task.

TABLE VIII. EFFECT OF WIND AND TURBULENCE, FEEL AND TRIM ON PILOT RATINGS

WIND AND TURBULENCE	FEEL AND TRIM													
	YES					NO								
	PILOT	Case No. 338	339	340	341	PILOT	Case No. 120	220	122	222	126	226	128	228
YES	D	7	7	7	7	A			6-1/2	5	4-1/2	4-1/2	7	7
	E	7	8	7	10	B	5	5					8	7
	F	7	7	7	7	C	7	4-1/2	7	7	5	5		
	PILOT	Case No. 342	343	344	345	PILOT	Case No. 334		335		336		337	
NO	D	3	4-1/2	4	4	D	4		4		4		4	
	E	2-1/2	4-1/2	2-1/2	3	E	3		4		3		5-1/2	
	F	2	4	3	3	F	2		2		3		2-1/2	

NOTE: Dynamic characteristics are defined in Tables I and II.

APPENDIX I

PILOT RESUMES

The flight experience of the evaluation pilots is summarized in the resumes provided in this appendix.

NELLO L. INFANTI

Mr. Infanti is the Chief Pilot of the Cornell Aeronautical Laboratory Flight Research Department. He has worked on many engineering projects and flight test programs at the Cornell Aeronautical Laboratory. These include many stability and control programs involving the B-26, F-94, and T-33 variable stability aircraft. He has conducted stability and control flight instruction of and demonstrations to U.S. Navy and Air Force test pilot school students, for all classes since 1963. He has also acted as evaluation pilot on many flight simulation programs, including: a research program which utilized the Johnsville centrifuge; programs on several airplane and V/STOL simulators and instrument trainers; and VTOL evaluations in the National Research Council of Canada variable stability helicopter. Mr. Infanti is a graduate of the USAF Experimental Test Pilot's School and has approximately 4,150 hours of flying time including over 3,000 hours of flight test in over 50 types of aircraft and rotorcraft.

ROGERS E. SMITH

Since joining the Cornell Aeronautical Laboratory in 1968, Mr. Smith has participated in the preparation of a VTOL Handling Qualities Specification. Prior to joining CAL he served as a pilot in the Royal Canadian Air Force, worked as an engineer and pilot for the National Research Council of Canada, and was a research pilot for the NASA Langley Research Center. While at the National Research Council, he performed evaluations of V/STOL handling qualities, using a variable-stability helicopter. At the Langley Research Center, he flew a variety of aircraft ranging from small helicopters to a supersonic trainer. Mr. Smith has approximately 2,500 hours of flying time including 450 hours in helicopters.

MAJOR THOMAS H. SMITH

Major Smith has been a pilot in the United States Air Force since 1954. His experience includes overseas tours in RB-66's and B-57's, and a high-altitude reconnaissance assignment in RB-57D's prior to his graduation from USAF Aerospace Research Pilot School. He is currently in V/STOL operations at Edwards Air Force Base. He has flown the XV-6A (P. 1127), S. G. 1262 (VAK 191) hover rig, two British air cushion machines, and the CV-8 Buffalo STOL transport. He also has flown evaluations in the NASA Ames Research Center six-degree-of-freedom simulator, the Ryan XV-5A simulator, the US/FRG simulator in Munich, Germany, and

the SV-4B simulator at Wright-Patterson Air Force Base. Major Smith's 5,300 hours of flying time include 50 hours in helicopters and experience in 34 types of aircraft.

MAJOR DAVID W. THOMAS

Major Thomas' experience includes seven years of operational and instructor duty in helicopters prior to his graduation from the USAF Aerospace Research Pilot School in 1964. Since then he has been in V/STOL Test Operations at Edwards AFB except for a 13-month overseas combat tour in A-1 aircraft in Vietnam. He has checked out in the XV-6A (P. 1127), the CV-8 Buffalo STOL transport, and the XH-51 compound helicopter. He has also flown the NASA Ames Research Center six-degree-of-freedom simulator, the Ryan XV-5A simulator, and the XV-4B simulator at Wright-Patterson Air Force Base. Major Thomas' 5,500 hours of flying time include 3,750 hours in helicopters.

CAPTAIN ROY E. PALMER, JR.

Captain Palmer has been a pilot in the United States Air Force since 1960. His experience includes five years in the C-130 prior to his graduation from the USAF Aerospace Research Pilot School. He is currently in V/STOL Test Operations at Edwards AFB. He has experience in several helicopters, is qualified in the XV-6A (P. 1127), and has served as project pilot for the Category II performance and stability and control testing of the O-2A. He has also flown the Ryan simulator. Captain Palmer's 3,400 hours of flying time include experience in 26 types of aircraft.

WILLIAM W. KOEPCKE, JR.

Mr. Koepcke is currently employed in the Northrop Norair Research and Development Department. At Norair he has participated as an engineer-pilot in several conventional aircraft and VTOL simulation studies, including an auto-rotation and stability augmentation failure study of the CH-46 helicopter; he has flown the Northrop T-38A and F-5B, and the experimental S-1. Prior to joining Northrop, he served in the U.S. Navy as an operational pilot with the fleet and as a test pilot at the Naval Air Test Center, Patuxent River, Maryland. He is a graduate of the U.S. Naval Test Pilot School. Mr. Koepcke holds conventional airplane and helicopter commercial flying licenses and has approximately 4,000 hours of flying time.

APPENDIX II

PILOT COMMENTS

Summaries of pilot comments for all three simulations are presented in this appendix. In a few of the cases, the comments are not available due to tape recorder malfunctions which were not discovered until the tapes were transcribed.

For each case, the stability derivatives and the constants of the airframe hovering cubic for the axes under evaluation are given in the headings. Also listed are the pilot ratings and the control sensitivities.

For the first two simulations, the main objectionable and favorable features are summarized at the beginning of each of the two sets of comments. These features are not necessarily the only objectionable or favorable ones that the pilot found but are the ones that he singled out in summarizing his comments. In some cases, the pilot did not do this. It is evident from these lists of objectionable and favorable features that for each pilot there were characteristics that seemed particularly important to him but might not be to another pilot.

For the third simulation, the objectionable and favorable features were not separated out as above. Instead these features are contained in the text of the pilot comments. However, headings are provided identifying these features so that they may be quickly ascertained without the necessity of reading the entire text.

FIRST SIMULATION

OBJECTIONABLE FEATURES

1. Attitude required to compensate for wind was too steep. Too great an attitude change was required to initiate motion or to maneuver.

PILOT A	:	112, 121, 122, 124, 125, 126, 127, 128, 129, 133, 134, 135, 136, 142, 144, 145, 148, 150, 151, 153 210, 123, 221, 222, 224, 225, 226, 227, 228, 229, 235, 236, 240, 242, 244, 245, 247, 248, 250, 253, 254
PILOT B	:	123, 124, 128, 130, 131, 133, 134, 136, 137, 138, 140, 141, 143, 145, 147, 149, 151, 152, 153 215, 220, 224, 223, 230, 232, 233, 234, 237, 240, 243, 245, 247, 251, 252, 253
PILOT C	:	120, 121, 123, 125, 126, 129, 131, 132, 135, 137, 138, 139, 141, 142, 144, 146, 152 220, 221, 222, 223, 225, 227, 229, 231, 238, 239, 241, 242, 244, 246, 248, 249, 250, 252

2. Airplane tended to be oscillatory, to have inadequate damping, to be unstable, to be prone to pilot-induced oscillations, or to get away.

PILOT A	:	202, 203, 204, 208, 212, 219, 225, 228, 233, 235, 242, 258
PILOT B	:	124, 128, 139, 153 215, 219, 224, 228, 254
PILOT C	:	106, 118, 131, 135, 139, 152, 158 202, 203, 209, 212, 222, 231, 235, 237, 239, 242, 248, 255, 256, 258

3. Response was too high-frequency, too quick, or too abrupt.

PILOT A	:	102, 103, 119, 135
PILOT B	:	101, 104, 108, 115, 119, 130, 136, 139, 141, 147, 151 233, 240
PILOT C	:	102, 103, 105, 109, 118, 121, 122, 135, 138, 142, 148, 155 218, 232, 237

4. Airplane responded to gusts too much.

PILOT A	:	112, 113, 122, 125, 126, 142, 144, 154 209, 229, 242, 258

OBJECTIONABLE FEATURES (Continued)

5. There was a tendency to overcontrol.

PILOT A : 155
253

PILOT B : 136
233

PILOT C : 105, 106, 117, 120, 131, 141, 146
203, 205, 207, 210, 211, 212, 217, 222, 223, 226,
227, 229, 231, 235, 248, 256

6. There was difficulty in establishing a precision hover.

PILOT B : 101, 104, 105, 107, 115, 116, 118, 119, 130, 131,
133, 134, 138, 140, 141, 143, 145, 147, 149, 152,
153
201, 204, 211, 217, 219, 220, 228, 232, 233, 234,
240, 243, 245, 251, 252, 253, 256, 257

PILOT C : 107, 117, 138, 141, 146
225, 226, 241

7. Response was too slow or too sluggish.

PILOT A : 116, 150
216, 234, 249, 251

PILOT B : 117

PILOT C : 111, 126
223, 246, 250, 256

8. It was difficult to perform the maneuvers with precision.

PILOT A : 126, 154
204

PILOT B : 139, 141, 149
201, 234, 243, 247, 254, 256

9. Constant attitude corrections, high control activity, or excessive pilot effort were required.

PILOT A : 115
236

PILOT B : 105, 107, 118, 132, 137, 140, 141, 149, 157
205, 207, 219, 232, 234, 241, 243, 251, 252, 253

PILOT C : 125, 144
211, 225, 255

OBJECTIONABLE FEATURES (Continued)

10. It was difficult to maintain an accurate ground track.

PILOT B : 131

PILOT C : 217, 235, 239, 241, 244

11, Airplane was uncomfortable to fly.

PILOT C : 103, 106
227, 237

12. There was a lack of precise, tight control.

PILOT B : 117, 118, 119, 128, 130, 134, 138
207, 217, 231, 237, 247, 257

13. It was difficult to maintain an attitude that would be practical for a vertical landing.

PILOT C : 120, 139, 141

14. Control displacements were too large.

PILOT B : 108

PILOT C : 252

15. Airplane had a tendency to slide laterally.

PILOT A : 230, 243

FAVORABLE FEATURES

1. It was easy to maintain the ground track or position over the ground.

PILOT B	:	104
PILOT C	:	122, 132, 137 207, 211, 212, 214, 238, 258

2. Performance of the tasks was reasonably good.

PILOT A	:	236
PILOT B	:	101, 115, 119, 133, 153, 157 204, 211, 251, 253, 257
PILOT C	:	103

3. Airplane was well-damped. There was no tendency for it to oscillate or get away. There was no PIO tendency.

PILOT A	:	136 209, 210, 213, 221, 226, 227, 229, 230, 240, 244, 247, 248, 250, 251
PILOT B	:	149 201, 215
PILOT C	:	110, 111, 112, 113, 121, 127, 150, 157 213, 244, 249, 250, 257

4. Airplane required very little nose-down or wing-down attitude to compensate for wind.

PILOT A	:	102, 103, 108, 110, 113, 147 202, 203, 208, 209, 212, 216, 233, 249, 255, 258
PILOT B	:	104, 115, 116 201, 204, 205, 207, 219, 254, 257
PILOT C	:	111, 150, 155, 157 210, 257, 258

5. A reasonable hover could be achieved. It was easy to make a transition to hover.

PILOT B	:	108, 141, 157 205, 207, 228, 237
PILOT C	:	106, 109, 114, 118, 122, 139, 156 202, 207, 209, 210, 211, 212, 213, 214, 218, 229, 238

6. The response to the controls was good, smooth, or precise.

PILOT A	:	140, 147 233
PILOT B	:	151 208, 215
PILOT C	:	139, 155, 156 205, 206, 214, 257

FAVORABLE FEATURES (Continued)

7. The response to gusts was good.

PILOT A	:	121
		210, 212, 213, 227, 255
PILOT B	:	219

8. There was no tendency to overcontrol.

PILOT A	:	140
		250
PILOT C	:	157

9. Airplane was easy, or not too difficult, to fly.

PILOT C	:	126, 132, 157
		213, 227, 238, 244, 250, 256

10. A hovering turn could be made at a good rate. The spot could be maintained in a hovering turn.

PILOT B	:	205, 245
PILOT C	:	118
		211, 238, 258

11. The response was smooth. There was no jerkiness.

PILOT C	:	112, 117, 157

12. It was easy to initiate motion.

PILOT B	:	118
PILOT C	:	114

CASE 101

X_u	=	-0.05	M_θ	=	-2.80
M_q	=	-1.65	ω_n	=	1.51
λ	=	0.5	ζ	=	0.40
$M_u g$	=	1.00			

PILOT A   PR = A3 M_δ = 1.24

Smooth control. No worry about overcontrolling. Quick stop easy; no feeling of slowing down. A certain pitch attitude resulted in the airplane going along as desired.

PILOT B   PR = A4 M_δ = 0.87

Control sensitivity was a compromise between what was desired and what could be stood because of abruptness in response. May have been better off with a lower sensitivity because of small abrupt kicks.

Attitude slightly nose-down, but pretty level. Probably small X_u.

Able to achieve fairly stable velocity and stop fairly well.

Precision of hover not great but adequate for a landing. Sometimes hover seemed pretty good. Could manage hover all right. Not really solid, but fair.

Turn over a spot was pretty good. Cross wind turn not too bad; pretty fair performance.

Attitude changes fairly mild in quick-stop maneuver. Collective requirements also fairly mild.

Felt sort of loose laterally.

CASE 102

X_u	= -0.05	M_θ	= -2.50
M_q	= -1.05	ω_n	= 1.50
λ	= 0.5	ζ	= 0.20
$M_u\, g$	= 1.00		

PILOT A PR = A3 M_δ = 1.03

Control sensitivity adequate.
No trouble with air taxiing.
Turn over a spot was easy.
Precision hover was satisfactory.
Quick stop was real good; could get some speed up.
Crosswind turn was no problem.

Response to gust was like a bump. Should have been more damped.

Little bit sloppy laterally. A little lateral wallow in crosswind turn.

No excessive attitude changes were required in pitch which was important. Nose was not required to be moved in pitch over a large amplitude to accelerate, and nose was level to hover in wind: the favorable feature without question.

PILOT C PR = A6 M_δ = 0.42

Control sensitivity set to give control response as smooth as possible. Control power appeared adequate but abrupt response caused worry about putting in large inputs. Seemed to have high-frequency dynamics.

No difficulty initiating motion or holding preselected rate of movement. Difficulty in stopping due to the abrupt response.

No excessive attitude changes necessary. Crosswind turns worked out well. No excessive delay, no overshoot or undershoot tendencies. No difficulty establishing heading.

Poor harmony of lateral and height dynamics with longitudinal. Rudder response and sensitivity adequate.

CASE 103

X_u	=	-0.05	M_θ	=	-2.30
M_q	=	-0.65	ω_n	=	1.50
λ	=	0.5	ζ	=	0.07
$M_u g$	=	1.00			

PILOT A PR = U7 M_δ = 0.96

Control sensitivity was adequate. When sensitivity was turned up, airplane responded too much.

Quick, disturbing reaction to a gust was the main objection. Like riding an airplane that was continually going up and down.

Very good feature was that it did not have to have too much pitch-down to initiate motion.

PILOT C PR = A6 M_δ = 0.40

Adequate control power.

No trouble initiating motion or holding preselected rate of movement. No excessive attitude changes required.

Great deal of attention to stay in the ground track.

Remained fairly well over the spot on the turn over a spot.

Crosswind turns not difficult; didn't take excessive time. No overshoot or undershoot tendencies.

Not too much difficulty in precision hover.

Stopped quickly in quick-stop maneuver.

Objectionable because of abrupt response. Tended to overcontrol or undercontrol. Uncomfortable to fly. Seemed to have high-frequency dynamics. Rudder control caused a little difficulty in heading control. Lateral and height dynamics did not affect evaluation.

CASE 104

X_u	=	-0.05	M_θ	=	-2.00
M_q	=	-1.95	ω_n	=	1.05
λ	=	1.0	ζ	=	0.48
$M_u g$	=	1.00			

PILOT A PR = A3 M_δ = 1.99

Control sensitivity was good.
No problem on square or hovering turn.
Quick stop was good.
Lateral-directional and height dynamics did not affect evaluation.

PILOT B PR = A4 M_δ = 0.71

Compromise in control sensitivity because of abrupt longitudinal pitch response. Probably this response was due to M_u. Almost constant hunting in pitch.

Air taxi was pretty good. Hover was fair.

Turn over a spot, fairly good. Probably had low X_u.

360-degree turns and stopping on heading were not problems.

Crosswind turns were not too bad.

Precision of hover was not as good as it should be.
Took too long but fairly good hover could be achieved. Lack of real precision in hover.

Quick stop was okay. Didn't achieve much speed. Fair to poor stop.

Attitudes seemed moderate and acceptable.

Rudder should be more responsive.

CASE 105

X_u	=	-0.05	M_θ	=	-1.60
M_q	=	-1.55	ω_n	=	1.04
λ	=	1.0	ζ	=	0.29
$M_u\, g$	=	1.00			

PILOT B PR = A5 M_δ = 0.70

Felt that control sensitivity should have been higher. Limiting factor was abruptness of response. This may have been a limitation of the simulator.

Air taxi was reasonably good. Ability to hold and stabilize rates was fair to poor. Ability to stop precisely was only fair.

Turn over a spot was fair. Work required was a bit high.

Crosswind turns were good to fair.

Precision of hover was only fair. Never really had a good stabilized hover.

Quick stop was not difficult at all. Got up to 20 kts.

Felt loose laterally. Height control was a bit outside of limits. Yaw control was good.

Would have liked force-feel system.

PILOT C PR = A6 M_δ = 0.50

Control sensitivity was not turned up excessively, but response was very abrupt. Not at all comfortable.

In the air taxi it was not too difficult to initiate motion but it was difficult to stabilize and hold this rate because of constant jerking back and forth. Very high frequency.

Difficult to stop precisely but not difficult to maintain a hover.

Attitude changes were slightly excessive.

Difficulty remaining in ground track due to overcontrolling. Overcontrolled in turns, longitudinally.

Quick stop worked out well. Stopped quickly but with a rather large attitude change.

Rudder control felt very sluggish. Took excessive lead in the crosswind turns.

Lateral-directional and height dynamics did not affect evaluation of longitudinal dynamics.

CASE 106

$X_u = -0.05$ $\qquad$ $M_u\, g = 1.00$

$M_q = -1.15$ $\qquad$ $M_\theta = -1.20$

$\lambda = 1.0$ $\qquad$ $\omega_n = 1.00$ $\qquad$ $\zeta = 0.10$

PILOT B $\qquad$ PR = A4 $\qquad$ $M_\delta = 0.74$

Felt control sensitivity chosen was a little too high.

Pretty good hover. Couldn't come to a good steady hover in a crosswind. Not bad downwind.

Crosswind turn was fair.

Quick stop was a mild stop.

Pretty good configuration. Precision not quite as good as desired. Took a little effort to initiate motion.

PILOT C $\qquad$ PR = A4-1/2 $\qquad$ $M_\delta = 0.44$

Control sensitivity was selected low enough to keep the jerkiness out of the system, yet with enough control power to keep stick movements at a minimum.

Easy to initiate motion and hold a preselected rate of movement. No difficulty stopping precisely and coming to a hover. No excessive attitude changes required.

In the turn over a spot, it was very easy to remain over the spot with no more than four or five degrees attitude change.

Crosswind turns worked well in rolling out, hovering, and establishing heading.

Quick stop was easily performed without excessive attitude changes, or difficulty in holding heading or attitude.

Height and lateral dynamics did not affect the evaluation of longitudinal dynamics.

System felt unstable and not comfortable. Tendency to slightly over-control and overshoot.

CASE 107

X_u = -0.05 $M_u g$ = 1.00

M_q = -2.25 M_θ = -1.81

λ = 1.5 ω_n = 0.80 ζ = 0.35

PILOT B PR = A4 M_δ = 0.75

Control sensitivity was set to where the feeling of hydraulic jumpiness was okay.

Able to initiate and stabilize motion fairly well in the air taxi. Not able to stop as precisely as desired.

Turn over a spot was fair. Took pretty fair amount of time to come to a hover on each heading.

Crosswind turns were fair. Difficulty achieving a good hover.

Could stop as quickly as needed in quick-stop maneuver. Attitude changes not excessive.

Overall precision of doing maneuvers was not quite as good as desired.

Lateral dynamics not good but not bad either. (Lateral stick sensitivity was doubled on this and subsequent longitudinal-evaluation runs.)

PILOT C PR = A6 M_δ = 0.27

Control sensitivity was set low to smooth out response. In doing so there was barely enough control power to perform some of the maneuvers.

Difficult to stay within limits around the square and very difficult to stop precisely and come to a hover.

Difficulty maintaining position in the turn over a spot.

Pitch attitude was rather steep to compensate for wind.

Crosswind turns were easy but it was difficult to come to a hover.

No excessive attitude changes were required in a quick stop. Maneuver turned out well.

Lateral-directional and height dynamics did not affect evaluation.

CASE 106

$X_u = -0.03$ $M_u g = 1.00$

$M_q = -1.35$ $M_\theta = -1.21$

$\lambda = -1.5$ $\omega_n = 0.82$ $\zeta = 0.24$

PILOT A PR = A3 $M_\delta = 1.16$

Control sensitivity might have been just a little too sensitive but it was pretty close.

Good ability to initiate motion with little pitch change.

Little pilot effort required in precision hover.

Great deal of confidence in making crosswind turns. No tendency to PIO.

Could get good speed up in the quick-stop maneuver.

Not too much nose-down required to hold into the wind.

PILOT B PR = A4 $M_\delta = 0.30$

Control sensitivity which eliminated a rather abrupt response seemed a little bit low so it was increased a little. Might have done better on the precision tasks if it had been a little lower but it wasn't bad.

Air taxi was only fair. Slight amount of lag in initiating forward motion. Reasonably easy to maintain stabilized rate of motion. Not able to stop as precisely as desired.

There were occasional pitch attitude changes in gusts which seemed moderately large. Apparently M_u was moderate.

Control felt loose with control motions on the high side. Bothersome abrupt initial response.

Turn over a spot not bad. Crosswind turns reasonable.

Had to expend moderate effort in precision hover.

Lateral dynamics did affect some of the maneuvers. Height control was not bad.

CASE 109

$X_u = -0.05$ $M_u g = 1.00$

$M_q = -1.45$ $M_\theta = -0.61$

$\lambda = 1.5$ $\omega_n = 0.83$ $\zeta = 0$

PILOT A PR = A3-1/2 $M_\delta = 1.31$

Air taxi was no particular problem. Required a little nose depression to go forward.

Some difficulty in turn over a spot.

Precision hover was satisfactory.

Good confidence in crosswind turn. Control activity and control power were adequate.

Quick stop was very smooth. Could stop as quickly as desired. No excessive attitude change required.

Couldn't control airplane and didn't feel quite as much at ease as would have liked.

PILOT C PR = A4 $M_\delta = 0.41$

Sensitivity set at a level required to control the vehicle.

Air taxi motion was easily initiated. Easy to stabilize and hold preselected rate. Some tendency to overcontrol. No excessive attitude changes necessary.

Turn over a spot was good to excellent. Easy to initiate turn and stop on heading.

Very simple to perform precision hover, although not a real comfortable feeling. Control inputs tended to bang vehicle around.

Vehicle stopped quickly in quick-stop maneuver but overshot with excessive attitude change.

Lateral-directional and height dynamics did not affect evaluation although they were poorly matched to the longitudinal system.

CASE 110

$M_u = -0.05$ $\qquad$ $M_{u_g} = 1.00$

$M_q = -3.15$ $\qquad$ $M_\theta = -2.03$

$\lambda = 2.5$ $\qquad$ $\omega_n = 0.56$ $\qquad$ $\zeta = 0.53$

PILOT A $\qquad$ PR = A3 $\qquad$ $M_\delta = 1.64$

Nothing drastically wrong with the air taxi.

No particular problem with the turn over a spot.

About two degrees nose-down were required to hover into the wind. Not much pitch attitude change required to fly.

No particular deficiency in the crosswind turn. It was adequate. No tendency to PIO.

Pitch change due to gusts was a little unpleasant. Sort of annoying.

Damping and frequency good.

PILOT C $\qquad$ PR = A2 $\qquad$ $M_\delta = 0.42$

Control power adequate with the sensitivity selected.

Air taxi was very simple. It was easy to initiate motion and hold preselected rate of movement. No problem stopping precisely and coming to a hover at the corners. No difficulty remaining over the ground track.

Rudder control was responsive. The rate was rather low but there was no difficulty holding heading.

Pleasant feeling system to hover.

Very little difficulty maintaining the center of the circle in the turn over a spot.

Overshot slightly on crosswind turns due to low yaw rate. No trouble establishing a heading or position.

No trouble establishing or maintaining precision hover. Very good for vertical landing.

On the quick stop, the airplane stopped as quickly as desired. No excessive attitude changes required.

Height control was easy.

Longitudinal and lateral systems not well matched; not real good control harmony. Lateral-directional dynamics did not affect the evaluation.

Well damped, no jerkiness. Frequency about right.

CASE 111

$X_u = -0.05$ $\lambda = 0.5$

$M_u g = 1.00$ $\omega_n = 1.51$

$M_q = -1.65$ $\zeta = 0.40$

$M_\theta = -2.80$

PILOT B PR = A3 $M_\delta = 1.24$

Pilot comments missing.

PILOT C PR = A3 $M_\delta = 0.29$

Generally a good system, easy to fly, no serious deficiencies.

Some difficulty remaining within the desired limits on the square.

Rudder control response was good. Sensitivity was low. No difficulty maintaining heading.

Had trouble remaining over the spot on 360-degree turn.

Some difficulty coming to a hover after crosswind turns.

No difficulty establishing a precision hover. Good system for vertical landings.

Easy to stop in quick-stop maneuver. No excessive attitude changes required.

Lateral-directional dynamics did not affect evaluation.

Response seemed slow and sluggish.

No tendency for PIO. No steep attitude changes necessary to initiate or stop motion.

CASE 112

X_u	$= -0.05$	λ	$= 2.5$
$M_u g$	$= 1.00$	ω_n	$= 0.64$
M_q	$= -2.45$	ζ	$= 0$
M_θ	$= -0.28$		

PILOT A   PR = A4 $M_\delta = 0.95$

With control sensitivity higher, the response was too oscillatory.

No excessive attitude changes required to initiate motion on the square or to hold over the ground in hover.

Quick stop was easy because it was easy to get up a good speed and it was very easy to stop.

No tendency to oscillate in crosswind turns.

Airplane was slightly responsive in pitch to gust input. This gave a discomforting nauseating feeling but didn't affect performance materially.

Pitch changes required during hovering turn were somewhat annoying.

PILOT C   PR = A2 $M_\delta = 0.48$

Easy to fly. No problem with PIO. No jerkiness.

Easy to initiate motion over the square and hold a preselected rate of movement. No problem stopping precisely at the corners or hovering. No excessive attitude changes required.

No difficulty remaining close to spot in the turn over a spot. No excessive attitude changes to maintain position.

No difficulty initiating turn rate with rudder or holding preselected turn rate.

Crosswind turns were accomplished in minimum time.

More than adequate for a safe vertical landing.

Able to attain close to thirty knots in the quick-stop maneuver and stop very quickly. No excessive attitude changes necessary. No tendency to PIO.

Height control requirement was normal. Lateral-directional and height dynamics affected ability to hover and make turns but didn't affect longitudinal evaluation.

CASE 113

X_u	= -0.05	λ	= 6.0
$M_u g$	= 1.00	ω_n	= ?.43
M_q	= -6.35	ζ	= 0.47
M_θ	= -2.27		

PILOT A — PR = A3 — M_δ = 1.86

Air taxi was satisfactory with slight nose-down requirement. Excessive attitude changes were not required at any time.

Not too much difficulty in turn over a spot.

Crosswind turn was no problem. No tendency to oscillate. Control sensitivity seemed adequate. Good control power.

Slight, bothersome tendency to pitch with small amplitudes due to gust input. Annoying, but did not affect flying characteristics.

Most important and best feature was that only one or two degrees nose-down was required to hold into wind. However, would prefer the nose to be absolutely level regardless of wind.

PILOT C — PR = A1-1/2 — M_δ = 0.46

Control sensitivity set at a level that gave very little jerkiness yet provided sufficient control power.

Easy to initiate motion around the square; easy to stop precisely and hover. No excessive attitude changes required.

Rudder response was good and harmony with longitudinal dynamics was good, but did not develop as high a rate of turn as desired. Easy to hold preselected turn rate and stop at preselected heading.

No overshoots in crosswind turn in either attitude or heading. Easy to establish heading after the turn and to position vehicle over ground.

Precision hover was very easy to fly. Adequate for a vertical landing.

No excessive attitude changes required for the quick stop.

Height control requirements were very low.

CASE 113 (Continued)

Lateral-directional dynamics did affect slightly the longitudinal evaluation. Lateral response was not matched exactly with longitudinal.

No overshooting or PIO tendencies.

CASE 114

$X_u = -0.05$ $M_u g = 1.00$

$M_q = -6.15$ $M_\theta = -1.07$

$\lambda = 6.0$ $\omega_n = 0.42$ $\zeta = 0.24$

PILOT B PR = A3 $M_\delta = 1.35$

Control sensitivity chosen was possibly a little high.

Some slight hesitation before starting motion in the air taxi. Good hover ability.

Crosswind condition was a little difficult. Lateral dynamics entered into the situation in the crosswind.

Fast speed in quick-stop maneuver. Able to stop right on the money.

PILOT C PR = A2 $M_\delta = 0.37$

Easy to initiate motion in every direction in the air taxi around the square and to hold a preselected rate of movement. No difficulty in stopping precisely at the corners or in coming to a hover. No excessive attitude changes in pitch were required but roll was over-controlled continuously.

On the turn over a spot, it was easy to maintain position and there were no excessive attitude changes required in pitch. Slight over-control in roll.

Crosswind turn resulted in slight overcontrol or undercontrol. No difficulty establishing heading or position on rollout.

Precision hover was easy to establish and maintain.

Vehicle stopped quickly in quick-stop maneuver.

Height control did not make the maneuvers more difficult.

Lateral dynamics affected the longitudinal performance but did not enter into the evaluation.

CASE 115

$X_u = -0.05$ $M_u g = 1.00$

$M_q = -5.95$ $M_\theta = 0$

$\lambda = 6.0$ $\omega_n = 0.41$ $\zeta = 0.02$

PILOT A PR = A5 $M_\delta = 1.98$

Had to exert too much control in pitch to do the desired things. Difficulty maintaining height.

Difficulty turning over a spot.

Would like less pitch motion.

Did not have any difficulty with the quick stop.

PILOT B PR = A4 $M_\delta = 0.95$

Control sensitivity turned up to the point of rapid abrupt response then backed off to get rid of it. Flew the evaluation maneuvers this way but thought that the sensitivity should have been higher.

Air taxi was only fair. Hover took a little more effort than should have been necessary and the precision wasn't as high as desired. A little too loose.

Rudder sensitivity was a little low.

Turn over a spot and crosswind turns were pretty good.

Adequate for vertical landing. Aircraft's response seemed to be somewhat delayed. Had to anticipate.

Able to maintain heading and ground track in quick-stop maneuver pretty well. Attitude changes required were moderate. Did over-control in pitch.

Height control generally was good. Had a tendency to climb when going aft, going laterally, or stopping.

Lateral dynamics were fairly compatible with longitudinal.

Vehicle was reminiscent of a light LOH.

CASE 116

X_u = -0.05 | $M_u g$ = 1.00

M_q = -3.00 | M_θ = 0

λ = 3.1 | ω_n = 0.57 | ζ =-0.05

PILOT A PR = A3-1/2 M_δ = 1.50

Control sensitivity was set a little high in order to overcome the effect of a lag between stick movement and nose movement.

Able to move the airplane right along in the air taxi. Did not sense an excessive attitude change to hold position.

No problem in crosswind turn. Had confidence in being able to handle airplane at all times.

Got up good speed in quick-stop maneuver. Didn't need much attitude change to effect motion.

Slight tendency to oscillate.

PILOT B PR = A5 M_δ = 1.50

Control sensitivity selected was perhaps too high, but lower values did not give tight enough control.

Vehicle may have been neutrally stable or even divergent.

Able to initiate motion and stabilize in the air taxi. Didn't have a good solid hover, but it was adequate for a vertical landing. Didn't like rapid, snappy, abrupt pitch response. Seemed to be overcontrolling. Felt uncomfortable.

Didn't do too well in the turn over a spot. Some PIO in the crosswind turn.

Quick stop was rather poor. Had trouble with altitude and hover.

Mismatch between lateral and longitudinal control. Lateral-directional dynamics did affect the evaluation to some extent.

It did not take excessive attitude changes to fly aircraft.

CASE 117

	X_u = -0.05		$M_u g$ = 1.00
	M_q = -2.0		M_θ = 0
	λ = 2.2	ω_n = .68	ζ = -0.12
PILOT B	PR = A5		M_δ = 0.80

Control sensitivity was limited by abruptness in response.

Was able to initiate motion in air taxi, but response of airplane lagged behind the control input. Fair control of motion. Could stop reasonably well, although not precisely. Needed quite a bit of pitch attitude change.

Attitude control in the turn over a spot was reasonable although the attitudes were sometimes high. Ability to stop on heading was pretty good.

Had more trouble setting up the crosswind turns than in making the turns themselves.

Could reach a precision hover but it was difficult to hold it. Tendency to change heading with drift.

Quick stop was no problem. Didn't pick up too much speed. Attitude changes were mild.

Airplane was loose laterally. Lateral dynamics affected the rating somewhat.

Didn't feel control was real tight. This was the primary objectionable feature.

PILOT C	PR = A5	M_δ = 0.30

Difficulty in stabilizing and holding preselected rate of movement on the square. Also difficulty in stopping precisely and coming to a hover. No excessive attitude changes required.

Difficulty in the turn over a spot and remaining over the spot.

Quick stop performed quickly without excessive attitude changes.

Lateral dynamics may have affected longitudinal dynamics due to overcontrolling laterally.

Control response was smooth with no jerkiness.

CASE 118

X_u = -0.05 $M_u g$ = 1.0

M_q = -1.00 M_θ = 0

λ = 1.5 ω_n = 0.82 ζ = -0.26

PILOT B PR = A5 M_δ = 0.96

Chose a control sensitivity which was a little high because of abrupt response.

Tendency to go too fast in air taxi. Lag in the initiation of motion. Tendency to overcontrol. Hover difficult. Attitude changes moderate. Strong tendency to drift away from the ground track.

Rudder sensitivity was a little low.

Turn over a spot wasn't too bad. Trouble establishing hover.

Trouble killing drift in hover to start crosswind turns. Achieved too great a velocity and overshot.

Couldn't hover precisely but it was adequate for a vertical landing.

Did quick stop well. Stopped where desired with only small attitude change.

PILOT C PR = A5 M_δ = 0.37

Felt a lot like the P.1127.

No difficulty initiating motion on square. Easy to stabilize and hold a preselected rate of movement. No difficulty stopping and coming to a hover. No excessive attitude changes necessary.

Easy to maintain position in turn over a spot. No excessive attitude changes in pitch or roll.

Able to hover after crosswind turn.

Precision hover was easy to establish and maintain although control inputs were being made all the time. Adequate for vertical landing.

Stopped quickly in quick-stop maneuver but overshot due to over-controlling. No excessive attitude changes required.

Height control did not make maneuvers more difficult. Lateral dynamics did not affect rating.

System felt unstable but controllable. Response slightly jerky or abrupt.

CASE 119

X_u = -0.05 $M_u g$ = 1.0

M_q = -0.30 M_θ = 0

λ = 1.1 ω_n = 0.94 ζ = -0.41

PILOT A   PR = A5 M_δ = 0.73

Would like less pitch movement to control hover position. Had to change pitch attitude more than desired.

Did not make a quick stop as quickly as desired. Had to make it smooth for fear of overcontrolling in pitch.

Rudder control adequate. Tendency to drift in the turn over a spot.

Height control made maneuvers more difficult. Lateral-directional control was all right.

Very abrupt pitch response. Difficulty making a smooth correction.

PILOT B   PR = A6 M_δ = 0.68

Difficulty in selecting control sensitivity due to quick, abrupt response. Value selected gave too abrupt a response. Strong tendency to overcontrol and get into PIO occasionally.

Ability to initiate motion in the air taxi was not too good. Trouble stabilizing the rate of motion. Not able to stop where desired. Control felt loose. Had to reduce pilot gain to avoid rapid inputs.

Rudder sensitivity felt a little low. Turn over a spot stayed within the circles fairly well. Able to stop reasonably well.

Precision of hover was poor. Couldn't achieve a well-stabilized hover. Never had a good solid hover. Could get into small amplitude, rapid pitching responses which seem to be self-induced. Pitch attitude was not too steep although occasionally the nose had to be held fairly low.

Quick stop was rather mild although a very high forward velocity could not be achieved.

Lateral-directional control was loose, which had some effect on the evaluation.

Barely adequate for vertical landing.

CASE 120

$X_u = -0.2$ $M_u g = 0.33$

$M_q = -2.10$ $M_\theta = -3.84$

$\lambda = 0.3$ $\omega_n = 1.91$ $\zeta = 0.52$

PILOT B PR = A5 $M_\delta = 0.82$

Could come to a pretty good hover by working at it, but not solid. Could probably land vertically.

Couldn't move very fast for a quick stop. About five degrees nose-down were required to maintain position.

Attitude changes from one heading to another created a problem in the turn over a spot.

Crosswind turns were fair.

PILOT C PR = U7 $M_\delta = 0.45$

Control sensitivity adequate without resulting in rather severe jerks that could produce PIO.

Easy to initiate motion around the square except into the wind. No difficulty holding motion, once established. Difficulty stopping at the corners. Excessive attitude change in pitch required for all changes in velocity.

Difficulty remaining over spot in the turn over a spot due to large attitude changes necessary.

Precision hover not too difficult once established. Difficult to maintain position over the ground which would make a vertical landing difficult.

Could not get going very fast for quick stop. Excessive nose-down pitch to initiate and hold forward velocity.

Height control did not make maneuvers more difficult. Lateral-directional dynamics poorly matched to longitudinal and had a bearing on controllability of vehicle if not on the longitudinal evaluation.

CASE 121

$X_u = -0.2$ $M_u g = 0.33$

$M_q = -1.30$ $M_\theta = -3.60$

$\lambda = 0.3$ $\omega_n = 1.87$ $\zeta = 0.32$

PILOT A PR = A6 $M_\delta = 1.24$

Required an undesirable amount of nose-down pitch to hover into the wind and to generate forward velocity. Not too much pitching with gusts.

Turn over a spot was extremely difficult because of the pitch changes required.

Crosswind turn was not bad if the vehicle was pitched down enough into the wind.

Difficult to accelerate forward for the quick stop.

PILOT C PR = A6 $M_\delta = 0.47$

Control sensitivity selected caused a definite jerkiness. Control power lower than desired.

Difficulty initiating motion on the square and difficulty stopping when downwind. Some difficulty in stabilizing and holding the preselected rate of movement.

Turn over a spot was uncomfortable to fly because of the extreme pitch attitudes necessary to compensate for wind.

Crosswind turns were done well and in a minimum amount of time.

Precision hover was not difficult to perform but the steep attitude would make a vertical landing very difficult.

Quick stop worked out well except for altitude. Some difficulty maintaining altitude.

Rudder control was good.

No tendency to PIO the vehicle.

CASE 122

$X_u = -0.2$ $M_u g = 0.33$

$M_q = -0.30$ $M_\theta = -3.30$

$\lambda = 0.3$ $\omega_n = 1.82$ $\zeta = 0.06$

PILOT A PR = A6-1/2 $M_\delta = 1.05$

Full control sensitivity (2.00) was much too high; airplane was much too sensitive. Could have been even lower than that selected.

Excessive attitude changes were required to move forward into the wind in the air taxi around the square. When retreating on the square even more pitch-down was required to stop. Pitch response to gusts was disturbing but not unstable.

Airplane required an undesirable amount of nose-down pitch to hover into the wind - at least six degrees.

The turn over a spot was extremely difficult because of the excessive pitch attitudes required.

Crosswind turn was not difficult if the airplane was pitched down enough when coming into the wind to prevent backing up.

Could not get up much forward velocity in the quick-stop maneuver.

PILOT C PR = A3 $M_\delta = 0.32$

A lower value of stick sensitivity did not give enough control to hover over a spot. A higher value resulted in definite jerky movements for any control input.

It was easy to initiate motion and to hold a preselected rate of motion while flying around the square. The ability to stop precisely and come to a hover at the corners was good. System appeared to be highly damped. No tendency to overshoot due to control inputs. Attitude change in pitch was slightly steeper than was comfortable to establish a forward velocity into the wind. Easy to remain within the ground track except for the gusts. Gusts caused a tendency to overcontrol.

It was easy to turn and remain over the spot. All controls were adequate. No difficulty stabilizing and holding preselected rate of turn or stopping on a preselected heading.

The crosswind turns were easy and comfortable to accomplish. No tendency to undershoot or overshoot. Moderately easy to maintain a position over a spot.

Precision hover was easy and the airplane would be fine for a vertical landing.

CASE 122 (Continued)

Could stop quickly with no excessive attitude changes in the quick-stop maneuver.

Lateral-directional and height dynamics did not affect the evaluation of the longitudinal dynamics to any great extent. Control activity was low throughout the flight.

(The above two pilot comment summaries are so different that an error in the vehicle dynamics might be suspected. However, an examination of dynamic check runs made immediately prior to each flight reveals the dynamics in each case to be identical.)

CASE 123

	$X_u = -0.2$	$\lambda = 0.5$	
	$M_u g = 0.33$	$\omega_n = 1.12$	
	$M_q = -1.30$	$\zeta = 0.45$	
	$M_\theta = -1.50$		
PILOT B	PR = 5 1/2	$M_\delta = 0.75$	

Difficulty initiating forward motion. Very nose-low attitude. Was able to stabilize motions fairly well on the square. Precision of control and stopping and coming to a hover over a corner was not very good. Ability to remain within the ground track was poor. Tendency to drift.

Stayed within the 25-foot circle on most of the headings in the turn over a spot. Seemed to require more effort to hover with the wind from the left than from the right.

Crosswind turn was a little sloppy to the right. Better performance to the left.

Precision of hover was fair. Adequate for a vertical landing.

Stopped quicker than desired in quick-stop maneuver. Overcontrolled the pitch attitude. Didn't pick up very much speed. Able to maintain heading and track fairly well.

Height control was moderately difficult.

Objectionable large, nose-down attitudes required.

PILOT C PR = A6 $M_\delta = 0.27$

Difficult to initiate motion around the square into the wind because of the steep attitude required. Once a rate of movement was established it was difficult to stop and come to a hover.

Some difficulty was experienced on the turn over a spot particularly because of the large nose-up attitude required with the wind from the back.

Crosswind turn worked out well although not much ground speed was attained prior to the turn into the wind.

Extreme nose-low attitude would make a vertical landing difficult.

CASE 123 (Continued)

Quick-stop maneuver was no trouble but was uncomfortable because of the very steep pitch attitudes required to establish a ground speed.

Height control did not make the maneuvers more difficult. Lateral dynamics did affect the longitudinal evaluation because of constant overcontrolling laterally.

CASE 124

	$X_u = -0.2$	$\lambda = 0.5$
	$M_u g = 0.33$	$\omega_n = 1.08$
	$M_q = -0.80$	$\zeta = 0.23$
	$M_\theta = -1.25$	
PILOT A	PR = U8	$M_\delta = 1.22$

Too much attitude change in pitch. Couldn't stay over the spot in the turn, due to pitch attitude change. Would lose reference.

Could stop quickly in quick-stop maneuver, but had slight overcontrol tendency.

Rudder control was all right.

PILOT B	PR = U8	$M_\delta = 0.70$

Control sensitivity reduced to a lower level than desired to avoid abrupt responses which may be due to the simulator hydraulics.

High drag configuration and M_u were probably also present. Tendency toward PIO.

Difficulty initiating motion in the air taxi in the forward direction. Rather large attitude changes required in pitch. Ability to stop at the corners and hover precisely not great. Quite a bit of drifting in all directions. Quite a bit of control activity and large stick motions.

Ability to turn over a spot was not good, particularly with a tail wind. Got into a PIO.

Didn't do a quick stop.

Had some difficulty with the height control. Lateral dynamics did have some effect on the evaluation.

CASE 125

X_u	= -0.2	λ	= 0.5
$M_u g$	= 0.33	ω_n	= 1.03
M_q	= -0.30	ζ	= 0
M_θ	= -1.00		

PILOT A PR = U7 M_δ = 1.31

Control became much too sensitive turned up to a higher value. It was then difficult to stabilize the oscillations due to gusts.

Required far too much nose-down to hold airplane into wind in hover and even more to then initiate motion on the square.

Airplane appeared to be unstable.

The turn over a spot was difficult due to attitude changes which varied from five or six degrees nose-down to the same amount nose-up. Gusts appeared to cause the airplane to diverge. Precision hover was not satisfactory due to attitude and also due to gusts.

Could not achieve much velocity for the quick-stop maneuver.

PILOT C PR = U9 M_δ = 0.41

Control sensitivity set to avoid a jerky, uncomfortable response.

Difficulty maintaining a rate of movement on the square because of the excessive pitch attitudes required. Difficulty stopping precisely over the corners and maintaining orientation due again to the attitude.

Difficulty turning and remaining over a spot because of erratic attitude control in pitch.

Difficulty stabilizing after a crosswind turn.

Precision hover was not difficult once established, but a vertical landing would be somewhat difficult due to the steep attitude required to correct for wind. Control activity was excessive in the hover.

Did not do a quick stop due to hydraulic dump.

Lateral-directional dynamics did not affect the evaluation. Height control was very difficult because of the steep changes in pitch attitude.

CASE 126

X_u	=	-0.2	λ	=	1.0
$M_u g$	=	0.33	ω_n	=	0.76
M_q	=	-1.80	ζ	=	0.[illegible]7
M_θ	=	-1.21			

PILOT A PR = A 4-1/2 M_δ = 1.26

Required excessive nose-down attitude to start up the square. Airplane sluggish moving forward.

Turn over a spot was difficult due to pitch attitude changes. Difficult to maintain a hovering position with a lot of nose-down attitude into the wind.

Didn't have any trouble with the crosswind turn.

Took a long time to move forward for the quick stop.

Slight pitching, jolting response to turbulence.

PILOT C PR = A5 M_δ = 0.37

Control sensitivity set high enough to allow enough control to compensate for wind. Sensitivity was not turned up higher because with too sensitive a control it felt that the airplane could get away. Control power seemed slightly low, however.

Very little difficulty initiating motion on the square. Not much trouble holding the preselected rate of movement. No difficulty in stopping precisely and coming to a hover at the corners, although the steep pitch attitude made it rather uncomfortable going forward and hovering with back to wind.

Turn over a spot was not too difficult although attitude control was erratic because of the large pitch changes needed to correct for wind.

Crosswind turns were accomplished in minimum time. No overshoot or undershoot tendencies. No difficulty in establishing heading after the turn.

Vertical landing would be difficult with the ten-knot wind.

No trouble stopping in the quick-stop maneuver. Some excessive attitude changes required.

CASE 126 (Continued)

Height control did not make the maneuvers more difficult. Directional control seemed well-matched to the longitudinal. Lateral was more sensitive and gave a tendency to overcontrol.

CASE 127

X_u	$= -0.2$	λ	$= 1.0$
$M_u g$	$= 0.33$	ω_n	$= 0.69$
M_q	$= -1.30$	ζ	$= 0.36$
M_θ	$= -0.71$		

PILOT A PR = A5 M_δ = 1.36

Excessive nose-down required to move forward into the wind. Excessive attitude change required to stop and in backward motion. Also in the hovering turn.

Crosswind turn required a large nose-down attitude to turn into the wind.

Could not get up much speed in the quick-stop maneuver.

Lateral wallowing to the left or right was noted.

PILOT C PR = A2 M_δ = 0.35

Control sensitivity selected gave an overall comfortable feeling though a little increase may have made the response more crisp. Felt like the P.1127 with a little damping.

It was easy to initiate motion in every direction in the air taxi around the square. Very easy to stabilize and hold a preselected rate of motion. Stops were made without excessive attitude changes rather precisely at the corners. Nose-down attitude on the first leg of the square was probably due to a quite fast speed acquired.

The turn over a spot was easy to perform. Easy to initiate a turn rate and stabilize on that rate. Turns were stopped at the preselected heading with little difficulty without overshoots or undershoots.

Crosswind turns were accomplished without overshoots or undershoots. It was easy to establish heading in position over the spot.

No difficulty in establishing and maintaining precision hover. System would be more than adequate for a vertical landing.

Stopped quickly after building up airspeed to 22 knots in the quick-stop maneuver. There were no excessive attitude changes.

Height control did not make the maneuvers more difficult. Rudder response was normal. Lateral dynamics could have had a bit more harmony with the longitudinal dynamics but did not affect the evaluation.

CASE 127 (Continued)

[The above two pilot comment summaries are so different that an error in the vehicle dynamics might be suspected. However, an examination of dynamic check runs made immediately prior to each flight reveals the dynamics in each case to be identical.]

CASE 128

	$X_u = -0.2$	$\lambda = 1.0$
	$M_u g = 0.33$	$\omega_n = 0.61$
	$M_q = -0.80$	$\zeta = 0$
	$M_\theta = -0.21$	
PILOT A	PR = U7	$M_\delta = 0.49$

Stick sensitivity was set very low. A higher value caused a very strong tendency for the airplane to oscillate. The low sensitivity resulted in a great amount of stick activity.

Excessive pitch-down attitude was necessary in hovering and to effect motion longitudinally.

Took too much pitch-attitude change, coupled with low stick sensitivity, to perform the turn over a spot satisfactorily.

Quick stop and crosswind turns also required too much nose-down pitch.

Airplane seemed sluggish laterally.

PILOT B	PR = U9	$M_\delta = 0.75$

Gear ratio was restricted to a lower value than would like because the abruptness in response could cause a PIO. Damping ratio was very low or the system may have been dynamically unstable.

Could not establish steady-state motion on the square or stabilize a hover very well. X_u is probably high. Also, M_u may be rather high.

The turn over a spot was fairly successful but lost the airplane in pitch trying to hover downwind. Got into a PIO and hit the stops. Difficult to turn due to large attitude changes.

Hover was poor throughout the evaluation, but adequate for a vertical landing.

Quick stop was good but resulting hover was very poor.

There were height control problems. Lateral dynamics felt loose and did enter into the evaluation.

CASE 129

	$X_u = -0.2$	$\lambda = 1.5$
	$M_u g = 0.33$	$\omega_n = 0.58$
	$M_q = -1.90$	$\zeta = 0.52$
	$M_\theta = -0.85$	
PILOT A	PR = A5	$M_\delta = 1.14$

Only major difficulty in the air taxi was the nose-down attitude into the wind. This affects the hover and the initiation of motion. Also the hovering turn.

Required 12 to 14 degrees nose-down to pick up speed for the quick stop.

Crosswind turns were well coordinated. Airplane was fairly stable. No tendency to oscillate. A little response to gusts was present.

PILOT C	PR = U7	$M_\delta = 0.26$

Control sensitivity was set fairly low. Increased sensitivity resulted in a definite jerking. Damping was about normal.

Easy to initiate motion while flying the square, although excessive attitude changes made altitude control difficult. Difficult to stabilize and hold preselected rate of movement because of the attitude. Also difficult to stop precisely and come to a hover at the corners.

Fairly easy to turn over a spot with a head or tail wind but difficult in a crosswind. Easy to initiate and hold a preselected turn rate but had some difficulty in stopping on a preselected heading because of overshoot tendencies.

Had a tendency to undershoot in rolling out of the crosswind turns.

Precision hover was fairly easy once established, but a vertical landing would be difficult because of the pitch attitude required to hold position.

Could stop quickly, but excessive attitude changes were necessary to perform maneuver. Control motions were large.

Except in a crosswind hover, lateral-directional dynamics had very little effect on longitudinal dynamics.

CASE 130

	$X_u = -0.2$	$\lambda = 1.5$
	$M_u g = 0.33$	$\omega_n = 0.52$
	$M_q = -1.60$	$\zeta = 0.29$
	$M_\theta = -0.40$	
PILOT A	PR = A3-1/2	$M_\delta = 1.06$

Fairly smooth in pitch without abruptness.

Didn't fly the square pattern too well, but felt that control of the airplane was good.

Drifted quite a bit in the turn over a spot, but again control felt good.

Precision hover was adequate for a vertical landing.

Control in effecting a smooth quick stop was good.

PILOT B	PR = A6	$M_\delta = 0.82$

Control sensitivity much higher than that chosen caused too abrupt a response.

It was difficult to initiate motion into the wind in the air taxi. Didn't stabilize too well. Stopping and hovering precisely was only fair. Had to work hard to establish a hover which would be adequate for a vertical landing. Pitch attitude activity was fairly high. Response not very smooth. Bank angle changes required in a crosswind seemed to be fairly high.

Attitude changes throughout the turn over a spot were fairly large. Pitch attitude is fairly large in a downwind hover, though the crosswind hover caused more trouble. Was able to stabilize the turn.

Crosswind turn could be made if done smoothly, otherwise the yaw rate was erratic and overcontrolling was possible.

Ground speed was low for the quick stop. Tendency to overshoot.

Moderate effort in height control. Lateral dynamics affect evaluation particularly in crosswind hover.

CASE 131

X_u	$= -0.2$	λ	$= 1.5$
$M_u g$	$= 0.33$	ω_n	$= 0.46$
M_q	$= -1.30$	ζ	$= 0$
M_θ	$= 0$		

PILOT B PR = U8 $M_\delta = 0.78$

Air taxi was very poor. Extreme nose-down attitude required. Difficult to stabilize, come to a stop, and hover decently.

Turn over a spot was very poor. Couldn't seem to stay over the spot, particularly downwind. Tendency toward PIO. Would be difficult to land downwind. Heading also caused problems.

Crosswind turns weren't bad, but hover was not good. Control activity was high.

Definite tendency toward PIO performing a quick-stop maneuver. Very excessive attitude changes. Difficulty maintaining a track. Altitude control was poor.

Lateral dynamics were annoying.

PILOT C PR = A6 $M_\delta = 0.39$

Control sensitivity could have been higher, but the ride would have been rougher.

Didn't have any trouble holding within the ground track in the air taxi, but did have trouble stopping at the corners. This was due to the excessive attitude changes necessary for movement. Difficult to come to a hover.

Had some difficulty remaining within the circle area in the turn over a spot. Again, this was due to the rather steep attitudes and a tendency to overcontrol longitudinally.

Crosswind turns worked out well except for the final hover.

Airplane could be landed vertically, but it would be uncomfortable because of the steep pitch angle.

Could not get up enough velocity to determine whether airplane could be stopped quickly in the quick-stop maneuver. Again, this was due to the excessive attitude changes required.

CASE 131 (Continued)

No trouble holding heading or altitude. Lateral-directional and height dynamics did not affect the longitudinal evaluation.

Possibility of PIO with large inputs.

CASE 132

X_u	=	-0.2	λ	=	2.5
M_{ug}	=	0.33	ω_n	=	0.47
M_q	=	-2.90	ζ	=	0.64
M_θ	=	-1.14			

PILOT B PR = A6 M_δ = 0.71

Workload heavy throughout the flight.

Could have used a little more control sensitivity, but a higher value caused a very abrupt response in attitude.

The air taxi was poor. Difficulty initiating motion going forward. Stabilization of forward motion and stopping precisely was fair to poor.

The turn over a spot was generally poor. Difficult to hover except directly into the wind. Bank angle with a crosswind combined with pitch-down gave trouble. Rudder control was all right.

Crosswind turns were not bad, but the time required to stabilize and set up for a vertical landing was too long.

Precision of hover was poor, but a vertical landing could be made slowly with effort.

Quick-stop maneuver was not difficult. Can stop rapidly. Attitude changes not excessive.

A force-feel system would be preferred to the no-force, no-centering system used.

PILOT C PR = A4 M_δ = 0.30

Air taxi around the square was easy to perform. No tendency to overshoot at the corners. Remained fairly close to the ground track.

Turn over a spot was difficult to perform because of the large attitude changes necessary to compensate for the wind.

After the first crosswind turn, it took an excessive amount of time to establish a hover. After the second one, there was no difficulty.

Precision hover required so much nose-down to compensate for the wind that there would be difficulty in performing vertical landings safely.

No tendency for PIO in the quick-stop maneuver. No difficulty holding heading or altitude.

CASE 132 (Continued)

Height control requirements did not make the maneuvers more dif icult. Lateral dynamics affected inputs in longitudinal axis since there was a tendency to overcontrol in the lateral axis.

CASE 133

X_u	=	-0.2	λ	=	2.5
$M_u g$	=	0.33	ω_n	=	0.40
M_q	=	2.60	ζ	=	0.38
M_θ	=	-0.39			

PILOT A   PR = A4 M_δ = 1.35

Control sensitivity good. No tendency to overshoot.

No trouble initiating motion in the air taxi around the square. Pitch attitude was a bit excessive nose-down. No particular trouble at hover.

Had difficulty in the turn over a spot when turning to the 180-degree position because of the transition from a fairly large nose-down attitude to nose-up. Drifted as a result. Rudder control adequate.

Crosswind turn was adequate. Quick stop worked out well.

PILOT B   PR = A6 M_δ = 1.12

Control sensitivity was a compromise between a high value needed for the rather large attitude changes required and a low value which reduced the abruptness of response but felt loose. Value selected resulted in quite a bit of the abruptness.

Able to initiate motion with difficulty in the air taxi. Could only stabilize for very slow rates. Could stop all right, but coming to a hover was extremely difficult. Pitch attitudes were excessive. Tendency to drift back going laterally. Lateral control felt loose. Rudder control okay.

Had good steady-state turn rate in the turn over a spot, but did not stay over the spot too well. In turning from downwind to crosswind, there was a tendency to drift.

Attitude control was reasonably good.

Ended up behind the spot in the crosswind turn. Overcontrolled in pitch.

Precision hover was poor. Control activity high. Could come to an adequate hover for landing, however.

Quick stop wasn't bad.

Height control was a problem. Lateral-directional dynamics were troublesome and did enter into the evaluation.

CASE 134

	X_u	= -0.2	λ	= 2.5
	$M_u g$	= 0.33	ω_n	= -.36
	M_q	= -2.40	ζ	= 0.19
	M_θ	= 0		
PILOT A	PR	= A4-1/2	M_δ	= 1.37

At the control sensitivity level selected, the pitch response was jerky.

Far too much nose-down attitude was required to initiate motion into the wind. No tendency to oscillate in pitch. Seemed well damped. Response was jerky. May have been the simulator rather than the airplane.

Difficult to fly a good four-point hovering turn over a spot due to attitude changes required.

Crosswind turn was satisfactory except for the large nose-down attitude required to prevent backing off of the spot at the completion of the turn.

Quick stop maneuver required too much nose-down to initiate velocity.

Lateral response seemed to have a definite phase lag.

PILOT B PR = U7 M_δ = 0.83

Control sensitivity compromised on the low side to avoid an abrupt response and a feeling that a higher value might cause an oscillation which would result in hitting the simulator stops.

Difficult to initiate forward motion in the air taxi and difficult to maintain any stabilized motion. Tendency to overcontrol when stopping. Fairly large attitude changes were required in pitch.

Fairly large attitude changes required in the turn over a spot. Rudder control lacked sensitivity.

Tendency to overshoot in the crosswind turns. Attitudes were fairly high.

Precision of hover fair to poor. Could come to a vertical landing with substantial effort.

Quick stop was fair. Ground speed seemed low. Didn't come to a very good hover.

Moderate height control activity. Lateral dynamics entered into crosswind hovers.

CASE 135

X_u	=	-0.2	λ	=	0.9
$M_u g$	=	0.33	ω_n	=	0.62
M_q	=	-0.30	ζ	=	-0.29
M_θ	=	0			

PILOT A   PR = A6-1/2 M_δ = 1.20

Control sensitivity limited due to very quick pitch response, though airplane seemed well damped.

Air taxi could be performed if done smoothly. Required excessive nose-down pitch to hover and go forward. Had to oscillate nose to stop forward motion. Far too much nose-down required to stop backward motion.

Turn over a spot required too much pitch change.

Had to be careful of this airplane in the crosswind turn because of its quick response. Tendency toward PIO, but it could be avoided.

Couldn't get up enough speed for a quick stop without getting the nose too far down.

Airplane was too quick in response; frequency was too high. Somewhat of a PIO airplane in pitch.

PILOT C   PR = U7 M_δ = 0.40

A higher value of control sensitivity made the response too jerky; a lower value did not provide enough control in the ten-knot wind. Difficult to fly. Had the feeling that any abrupt maneuvers could definitely develop into a PIO.

Had difficulty initiating motion in the forward direction into the wind on the air taxi around the square because of the steep pitch attitudes required. Once a rate of movement was established, there was not too much difficulty holding it. Excessive attitude changes were required to become established in a hover at the corners. Once the vehicle was in a hover, it wasn't difficult to hold.

Had difficulty remaining over the spot in the turn because of the steep changes in pitch required. Rudder control was adequate, but was not well matched to the longitudinal control. System felt as if it would get into a PIO with full rudder input.

Crosswind turn turned out well. Not too much difficulty with heading control.

CASE 135 (Continued)

Control activity in hover was excessive. Vertical landing would be difficult.

Quick stop almost resulted in a PIO and losing control. Excessive attitude changes were required and control motions were large.

Lateral-directional and height dynamics did not affect the evaluation.

CASE 136

X_u	=	-0.2	λ	=	3.0
$M_u g$	=	0.33	ω_n	=	0.33
M_q	=	-3.00	ζ	=	0.24
M_θ	=	0			

PILOT A   PR = A4 M_δ = 1.44

Large objectional nose-down attitude required to initiate forward motion into the wind. Difficulty in holding a preselected rate of movement, and in stopping precisely and coming to a hover because of the attitude.

No noticeable oscillation, but a lag between stick input and pitch response was evident.

Turn over a spot was impaired by the objectional attitude changes. Rudder control was all right.

Objectional feature of the precision hover, quick stop, and crosswind turn was the nose-down attitude.

PILOT B   PR = A6 M_δ = 1.13

Control sensitivity may have been set a little high. Response was rather abrupt.

Difficult to initiate forward motion due to nose-down attitude required. Approached simulator stops so the tendency was to push over slowly. Could stabilize forward motion with large attitude change. Had to work to establish the hover points.

The turn over a spot was only fair due to the attitude changes required. Downwind direction with nose-up was particularly objectionable.

Crosswind turns were fairly good overall , but it was difficult to judge the point at which to start the pitch attitude change required to stop. Tendency to overcontrol.

Precision of hover was poor. A lot of control activity and rather large attitude changes. Tendency to overcontrol.

Quick-stop maneuver was very bad. Got into some sort of PIO. Altitude control contributed to the difficulty.

Secondary dynamics enter into the evaluation because of the mismatch between lateral and longitudinal control sensitivities.

CASE 137

X_u	=	-0.2	λ	=	0.5
$M_u g$	=	1.00	ω_n	=	1.90
M_q	=	-1.80	ζ	=	0.40
M_θ	=	-3.98			

PILOT B   PR = A5 M_δ = 0.75

Pitch attitude in the air taxi was generally excessive.

The turn over a spot was difficult due largely to the crosswind hover. Rudder sensitivity could be a little higher. Had some difficulty holding heading.

Had trouble stabilizing to hover after the crosswind turns.

Precision of hover was only fair. Adequate for vertical landing.

Difficulty getting up any ground speed for the quick stop. Attitude seemed extreme.

Height control was fairly good. Lateral dynamics probably had some effect on the evaluation.

Probably should have chosen a higher pitch-control sensitivity.

PILOT C   PR = U7 M_δ = 0.53

Control sensitivity set high enough to give the desired response yet not so high that the response was jerky.

Had no difficulty initiating motion, although it required a very steep attitude to translate into the wind. Could hold a preselected rate of movement, although the steep attitude caused trouble remaining within the ground track.

The turn over a spot was very difficult because of the pitch attitude.

The crosswind turns worked out well, although it took too much time to come to a hover. Control activity moderate to heavy in this maneuver. Unable to roll out precisely on heading.

Precision hover was easy to maintain once established. It was not adequate for a vertical landing because of the steep attitude required.

Could stop quickly in the quick-stop maneuver. The attitude change required to initiate motion and to maintain the desired rate was excessive.

Lateral-directional and height dynamics did not affect the evaluation.

CASE 138

X_u	= -0.2	λ	= 0.5
$M_u g$	= 1.00	ω_n	= 1.87
$\dot{M}_q$	= -1.30	ζ	= 0.27
M_θ	= 3.73		

PILOT B   PR = U8 M_δ = 0.81

Control sensitivity limited by abruptness in response.

Difficulty initiating motion going forward and stopping. Couldn't stabilize velocities. Attitude changes quite large. Suspect high X_u. Overcontrolled laterally.

The turn over a spot was very bad. Difficult to establish a heading and come to a hover.

Crosswind turns were very sloppy. Tendency to drift backwards.

Precision of hover was very bad. Probably could make a vertical landing. Control activity heavy throughout.

Quick stop was very poor. Difficulty starting motion and also stopping.

Height control was very bad. Lateral configuration looks bad because of the bad longitudinal one.

PILOT C   PR = A6 M_δ = 0.37

Had no difficulty initiating motion, but it was difficult to maintain a preselected rate to stop at the corners, and to establish a hover due to the steep pitch attitudes required. Also difficult to remain close to the ground track.

On the turn over a spot, it was difficult to remain over the spot. Overshot desired headings.

Constant control activity due to a jerky response to stick inputs.

Once established in a precision hover, it was not difficult to maintain. With the nose-low attitude, it would be difficult to perform a precision hover.

Was able to stop correctly in the quick-stop maneuver, although did not have the desired forward velocity. Required an excessive attitude change.

Height control and lateral-directional dynamics did not affect the evaluation.

CASE 139

X_u	= -0.2	λ	= 0.5
$M_u g$	= 1.00	ω_n	= 1.84
M_q	= -0.70	ζ	= 0.11
M_θ	= -3.43		

PILOT B PR = U9 M_δ = 0.65

Control sensitivity limited by quick, jerky, abrupt response which may have been a simulator limitation. The sensitivity chosen required fairly large control inputs.

Large attitude change was required to initiate motion. Assumed that this was a high X_u condition. Not possible to do any precision hovering at all. Amount of stick motion required was much too great. Ability to hold heading was not very good because of the nose-low attitude.

The turn over a spot was bad. Could not remain over the spot at all. Almost impossible to hover downwind with the very nose-high attitude required. Was not able to stabilize and hold a preselected turn rate due to the effort required to stay over the spot.

Crosswind turns were not very good. Required quite a bit of effort to get close to the spot.

Precision hover was very poor. Doubtful whether a vertical landing could be made. Very heavy control activity.

Could never get going very fast for a quick stop. Airplane stopped almost immediately with a combination of attitude and collective control.

Height control was a problem. Lateral dynamics rather sluggish.

PILOT C PR = U7 M_δ = 0.47

Difficulty initiating motion on the air taxi around the square, and difficulty holding a preselected rate of movement due to steep pitch attitudes. Did not have difficulty stopping at the corners, but could not be precise on selecting the hover spot.

The turn over a spot was difficult due to the large attitude changes necessary in the longitudinal axis in order to stay fairly close to the spot on the ground. Rudder response was low on sensitivity.

Crosswind turns were accomplished in a minimum of time without overshoot or undershoot tendencies. No difficulty in establishing heading or position over the spot after rollout. Control activity was moderate to heavy.

CASE 139 (Continued)

Was able to establish and maintain a precision hover but the attitude and angular rates necessary for a vertical landing would have made this practically impossible.

The quick stop maneuver required a very steep pitch change to establish a forward translation though the stop itself was performed quickly without an excessive attitude change. No difficulty in holding heading or altitude.

Lateral and height dynamics did not affect the longitudinal evaluation.

System was not divergent but lacked damping.

CASE 140

X_u	=	-0.2	λ	=	1.0
$M_u g$	=	1.00	ω_n	=	1.20
M_q	=	-2.80	ζ	=	0.50
M_θ	=	-2.25			

PILOT A   PR = A3-1/2 M_δ = 1.40

Control satisfactory. No overcontrolling problem. Performance not good on the square or in the turn over a spot.

Adequate for a vertical landing.

Quick stops smooth.

PILOT B   PR = U7 M_δ = 1.05

Longitudinal control sensitivity was on the high side, but control felt better for the large attitude changes required if the sensitivity was increased. However, response was rather quick and abrupt.

Air taxi was rather poor. Difficult to start motion and difficult to hover precisely. Excessive attitude changes required.

Turn over a spot was sloppy. Rudder control lacked sensitivity. Hover difficult in any of the directions. Could initiate turns and hold preselected headings all right.

Crosswind turns were poor. Couldn't get moving into the wind and ended up short of the spot. Hover was not easy.

Precision hover was poor. Attitude changes required were too large. Vertical landing doubtful. Too much control activity.

Quick stops were poor. Too much nose-down.

Considerable height control activity required. Lateral dynamics did enter into the evaluation. Some mismatch evident between the lateral and the longitudinal.

CASE 141

X_u	=	-0.2	λ'	=	1.0
$M_u g$	=	1.00	ω_n	=	1.15
M_q	=	-1.40	ζ	=	0.26
M_θ	=	-1.65			

PILOT B PR = A4 M_δ = 0.68

Difficulty in stabilizing the forward velocity into the wind. Initiation of motion seemed difficult in the air taxi.

Able to remain over the spot reasonably well in the turn over a spot. Drifted in the turn from southerly heading to easterly heading. Rudder sensitivity a little low to initiate a turn. Could stabilize fairly well in a turn and stop reasonably well.

Crosswind turns were not too bad.

Precision of hover was not too bad. Able to reach a fairly good stabilization. Have to work, however. Adequate for landing.

Quick stop was a mild maneuver. Can stop quickly. Attitude change somewhat excessive.

Height control was a problem, particularly in downwind hovering. Lateral dynamics are objectionable due to a roll oscillation. This may be partly pilot induced.

PILOT C PR = U8 M_δ = 0.35

Control sensitivity was set low; yet, the response for small inputs seemed large. Tended to overcontrol.

Had difficulty initiating motion in the air taxi around the square because of the steep angles required to compensate for the wind. Difficulty stopping precisely and coming to a hover. Excessive attitude changes were necessary when translating into or away from the wind. Difficulty remaining within the ground track.

Stayed fairly close to the center in the turn over a spot. Attitude control was very difficult. Rudder control seems slow; sensitivity low.

Had difficulty in the crosswind turn establishing any forward velocity because of the steep attitudes required. Difficulty coming to a hover after rollout.

Could hover, but not precisely. Vehicle would have been very difficult to land vertically.

CASE 141 (Continued)

Stopped quickly in the quick-stop maneuver, although the forward velocity was not very large. Overshot in pitch due to overcontrolling. Had difficulty holding heading.

Height control was erratic. Did not make the maneuvers more difficult although limits on altitude control were exceeded.

Lateral dynamics were in harmony with longitudinal, but both systems were not satisfactory.

CASE 141 RERUN

x_u	= -0.2	λ	= 1.0
$M_u g$	= 1.00	ω_n	= 1.15
M_q	= -1.40	ζ	= 0.26
M_θ	= -1.65		

PILOT B   PR = A 6-1/2 M_δ = 0.81

Control sensitivity compromised because of the abruptness in response. Seemed to be a lag between control input and response.

Major problem in the air taxi was initiating forward motion. Had trouble stablizing the speed. Trouble in stopping precisely. Response to gusts was abrupt and indicated M_u present.

Not able to remain over the spot in the turn maneuver. Some rather large attitude changes required in the turn. Rudder lacks sensitivity, but could stop fairly well.

Crosswind turns were fair but lacked precision in coming to a hover over the spot.

Precision hover required a large amount of effort to be able to start a landing.

Ground speed was low in the quick-stop maneuver. Nose low.

Height control required effort. Lateral dynamics were less trouble than longitudinal.

CASE 142

$X_u = -0.2$ $\lambda = 1.0$

$M_u g = 1.00$ $\omega_n = 1.12$

$M_q = -1.00$ $\zeta = 0.09$

$M_\theta = -1.25$

PILOT A PR = A6 $M_\delta = 1.32$

Control sensitivity set to give an airplane response that seemed fast enough.

Performance was bad due to the large nose-down attitude required to hold into the wind and to accelerate into the wind. Ability to stop precisely and come to a hover at the corners was bad. Pitch response to gusts was annoying.

The turn over a spot was difficult. Crosswind turns were not very good. Quick stop was difficult to evaluate because of the severe nose-down attitude which resulted from an endeavor to get up any velocity.

No tendency toward PIO.

PILOT C PR = A5 $M_\delta = 0.44$

Difficult to establish a correct or good-feeling sensitivity.

Fairly easy to initiate motion on the air taxi around the square, although the pitch attitude was much steeper than comfortable in order to move into the wind. No difficulty stopping precisely at the corners and hovering, although there were, again, rather steep pitch changes required to make any change in rate of movement.

Difficult to remain over the spot in the turn over a spot due to the large pitch changes required during the maneuver. Rudder control was adequate though the sensitivity was perhaps low for harmony with the longitudinal system.

No difficulty in the crosswind turns. No overshoot or undershoot tendencies and no difficulty in establishing heading in position over a point.

Once established in a precision hover, it was easy to maintain although the attitude was such that a vertical landing would be difficult.

Vehicle could perform a quick stop as quickly as desired, but a large attitude change was required for the maneuver, particularly to initiate motion over the ground.

CASE 142 (Continued)

Height control didn't seem to affect flight in the tasks and was quite easy considering the steep pitch attitude the vehicle was in. Neither height dynamics nor lateral-directional dynamics affected the evaluation.

Response slightly jerky.

CASE 143

$X_u = -0.2$ $\lambda = 1.5$

$M_u g = 1.00$ $\omega_n = 0.94$

$M_q = -2.10$ $\zeta = 0.43$

$M_\theta = -1.67$

PILOT A PR = A5 $M_\delta = 1.37$

Just couldn't fly this airplane smoothly. Didn't feel good.

PILOT B PR = U7 $M_\delta = 0.81$

Control sensitivity was a compromise because of the abruptness of response.

Was able to initiate motion and stabilize fairly well going forward. Apparently this was a high X_u condition with some M_u. Precision of hover was not great due to large pitch attitudes required for corrections in drift.

Had difficulty remaining over the spot in the turn over a spot, particularly when hovering downwind. Downwind the nose was high and it felt unnatural. Rudder control was okay. Ability to hold heading was not too good.

The crosswind turns caused trouble due to inability to drop the nose at the proper point to keep from drifting aft.

Control activity in hover was appreciable and precision poor but a vertical landing could be made. Control activity was fairly high.

Cannot achieve very much forward velocity for a quick stop, hence the maneuver didn't take much control. Was able to hold heading okay.

Height control was a problem. Lateral dynamics felt loose.

Came close to a PIO on occasion.

CASE 144

$X_u = -0.2$ $\lambda = 1.5$

$M_u g = 1.00$ $\omega_n = 0.90$

$M_q = -1.70$ $\zeta = 0.22$

$M_\theta = -1.07$

PILOT A PR = A6 $M_\delta = 0.41$

Had to lower the nose too far to hover into the wind. Airplane had an annoying jerky response.

Drifted considerably in the turn over a spot because of the nose-up attitude or nose-down attitude.

Quick-stop maneuver worked out badly due to pushing the nose down too far and almost losing control after pulling the nose up quickly.

After turning into the wind on the crosswind turn maneuver, the airplane seemed to come to a stop.

PILOT C PR = A4 $M_\delta = 0.41$

It was easy to initiate motion for the air taxi around the square, although the pitch attitude appeared excessive to establish forward velocity. Fairly easy to hold a preselected rate of movement. Some overshooting when coming to a stop at the corners.

The turn over a spot was a little difficult to perform due to excessive pitch attitudes. It was fairly easy to stabilize and hold a preselected turn rate and there was no trouble stopping on the preselected heading. Rudder control was adequate.

Crosswind turn was fairly easy to perform without overshoot or undershoot. There was very little change in altitude and it was easy to establish heading after the turn. Control activity was somewhat high, however.

Precision hover was fairly easy to maintain into the wind. Crosswind was a little more difficult. It was adequate for a vertical landing. Again, control activity was a little high.

Attitude changes were rather excessive for the small ground speed attained during the quick-stop maneuver.

Height control did not make the maneuvers more difficult. Control harmony was fairly good.

CASE 145

$X_u = -0.2$ $\lambda = 1.5$

$M_u g = 1.00$ $\omega_n = 0.87$

$M_q = -1.40$ $\zeta = 0.06$

$M_\theta = -0.62$

PILOT A PR = A4 $M_\delta = 1.13$

Longitudinal sensitivity was satisfactory. Lateral felt a little sloppy.

Excessive, objectional nose-down pitch required to maintain a forward velocity on the square pattern when moving into the wind. Required nose-down to hover, also. Tendency to back up when stopping forward motion due to bringing the nose up too far.

No trouble on the hovering turn but had to carefully raise the nose very high when downwind.

Did not have good forward velocity to properly evaluate the quick stop due to excessive nose-down attitude that would have been required.

Slight lag between stick input and response. Damping appeared to be high.

[An examination of a dynamic check made immediately prior to this run indicates that the damping was correct, approximately 0.06.]

PILOT B PR = U7 $M_\delta = 0.85$

Might have liked a somewhat higher control sensitivity, but a higher value tended to cause a PIO.

Could not stabilize on a very high velocity in the air taxi. Can stop where desired, but there was a tendency to end up going backwards. Attitude changes were excessive.

Longitudinal response felt tight; the lateral, loose. In the nose-low attitudes, the stick was held forward and the stick was rather heavy.

The turn over a spot worked out well. Ability to hover was poor all the way around the turn. Probably adequate for a landing. Control activity was excessive.

Quick stop wasn't too bad. Heading was not a problem but altitude was.

Height control was a problem throughout. Lateral dynamics affected the overall performance.

CASE 146

$X_u = -0.2$ $\lambda = 2.5$

$M_u g = 1.00$ $\omega_n = 0.69$

$M_q = -2.70$ $\zeta = 0.29$

$M_\theta = -0.93$

PILOT B PR = A5 $M_\delta = 0.74$

Fairly nose-low situation throughout the flight. This makes precision of control difficult because the attitude corrections are usually quite large.

Was able to initiate motion for the air taxi with difficulty longitudinally. Laterally, it was better. X_u is probably large and causing the difficulty. Stabilizing a rate of motion longitudinally also was a problem. Could stop at the corners fairly well and hovering was fair.

Excessive attitude changes in the quick stop. Turn over a spot was fair.

PILOT C PR = A6 $M_\delta = 0.30$

Air taxi around the square was difficult because of the steep attitude into the wind. Difficult to stabilize at the corners.

Difficult to remain close to the center of the circle in the turn over a spot. Turn was erratic due to the steep attitude changes necessary to compensate for the wind.

Following the crosswind turns, a great deal of time was required to come to a precise hover. Control activity was heavy.

A vertical landing would be difficult because of the steep attitude.

Could not get much forward velocity into the wind for the quick stop.

Height control requirements did not affect the maneuvers. Some overcontrolling in the lateral axis occurred.

CASE 147

$X_u = -0.2$ $\lambda = 2.5$

$M_u g = 1.00$ $\omega_n = 0.73$

$M_q = -3.00$ $\zeta = 0.48$

$M_\theta = -1.68$

PILOT A PR = A2 $M_\delta = 0.82$

Could not fly with sensitivity turned up higher, so it was turned back down to about the center of the knob travel.

Able to initiate motion quickly without too much nose-down. Able to stabilize and hold a selected rate of movement. There were no excessive attitude changes required in pitch. Very little lag in the pitch response to stick motion. Amount of stick activity was satisfactory.

Ability to turn over a spot was not exceptional but the control motion was not excessive. Pitch attitude changes were not excessive.

Able to hover over a spot with relative ease because pitch could be controlled with small stick movements.

Crosswind turn was satisfactory. Could put it over the spot. Quick-stop maneuver was good.

Airplane was sluggish in roll, otherwise no objectional secondary dynamics.

PILOT B PR = A6 $M_\delta = 1.01$

Control sensitivity was perhaps set a little high. The response for small rapid inputs was somewhat abrupt.

Ability to initiate motion into the wind in the air taxi was poor. Had difficulty stabilizing motion. Not able to stop precisely at the corners. Tendency to undershoot and overshoot. Hover was fair to poor.

The turn over a spot was good despite the large attitude changes required. Rudder response was low, but ability to turn was okay. Didn't stabilize too well, but stopping on a preselected heading was okay.

Crosswind turns were fair but there was a tendency to undershoot the spot. Control activity was moderate.

Precision of hover was not very good, but it was precise enough to start a vertical landing. Control activity was high in the hover.

Could hardly get moving forward for the quick stop.

CASE 147 (Continued)

Height control was fair. Secondary dynamics do enter into the evaluation.

[The above two pilot comment summaries are so different that an error in the vehicle dynamics might be suspected. However, an examination of dynamic check runs made immediately prior to each flight reveals the dynamics in each case to be identical.]

CASE 148

$X_u = -0.2$ $\lambda = 2.5$

$M_u g = 1.00$ $\omega_n = 0.63$

$M_q = -2.30$ $\zeta = 0$

$M_\theta = 0$

PILOT A PR = A3 $M_\delta = 1.37$

Control sensitivity selected seemed all right, except that the response was a little too rapid.

The main objection with the airplane in the air taxi around the square was that the nose had to be held down considerably in order to initiate any motion. Difficult to decide where the hover attitude is and how to start and stop from that attitude. Difficult to back up on the square.

Objection to the turn over a spot is that the nose must be down considerably when facing into the wind and up considerably when facing downwind. Hence, it is difficult to coordinate attitude around the turn in order to maintain position over the ground.

Quick-stop maneuver has the objectional feature of requiring a large nose-down attitude in order to pick up any speed at all to evaluate a quick stop. Easy to stop, but there is then a tendency to back up. This last comment also applies to stopping after the crosswind turns.

PILOT C PR = A5 $M_\delta = 0.46$

Control sensitivity was set high enough to give enough control to compensate for the wind. However, this sensitivity gave a rather hard, uncomfortable control feel.

It was easy to initiate and maintain a preselected rate of movement in the air taxi around the square. Fairly easy to stop precisely and come to a hover at the corners.

Some difficulty staying over the spot in the turn over a spot perhaps because of gusts. Excessive attitude control was not necessary to maintain spot once established. Turn rates were established and stabilized throughout the turn without difficulty. Stops were made without difficulty on preselected headings.

Crosswind turns were accomplished expeditiously without overshoots or undershoots. Easy to establish a heading in position over a spot. Control activity was moderate.

CASE 148 (Continued)

A precision hover was easy to hold once established but disturbances tended to be divergent.

Could stop very quickly in the quick-stop maneuver, and the attitude changes were not excessive. Control motions were moderate.

Height control was not difficult and did not affect the evaluation.

CASE 149

$X_u = -0.2$ $\lambda = 6.0$

$M_u g = 1.00$ $\omega_n = 0.48$

$M_q = -6.30$ $\zeta = 0.52$

$M_\theta = -1.97$

PILOT A PR = A3 $M_\delta = 2.00$

Control sensitivity could have been perhaps a little less, but it was not too objectionable at the level selected.

Control in the air taxi around the square was reasonably good. Damping was very good. Had no qualms about moving the airplane around. Excessive attitude change was required, however.

The turn over a spot was very good. No trouble controlling a precision hover. Crosswind turn was adequate. Could get reasonably close to the spot. The quick-stop maneuver required excessive attitude changes.

PILOT B PR = A5 $M_\delta = 1.41$

Initiation of forward motion in the air taxi was slow. Able to stop fairly well but establishing a hover was more difficult. Attitudes were not too great but control activity was high. Response to rudder and ability to hold heading were fair.

The turn over a spot was fair. Attitudes were fairly high. Able to initiate and achieve a reasonable turn rate. Able to stop reasonably well.

Crosswind turns were fair. Control activity was high in the maneuver and for the hover.

Precision hover was not as precise as desired, but a vertical landing could probably be achieved. Required constant control activity.

Never got going very fast for the quick-stop maneuver. Stop was mild.

Moderate difficulty in height control. Lateral dynamics did affect the evaluation.

No tendency toward PIO.

CASE 150

X_u	=	-0.2	λ	=	6.0
$M_u g$	=	1.00	ω_n	=	0.44
M_q	=	-6.10	ζ	=	0.33
M_θ	=	-0.77			

PILOT A PR = A5 M_δ = 2.00

Used high control sensitivity because the airplane was extremely sluggish and overly damped. Airplane was well behaved and responded to stick movements readily. Gust response seemed negligible.

In the air taxi around the square, and in all the other maneuvers, excessive pitch altitude changes were required to initiate and maintain motion into the wind.

The turn over a spot was not bad but required coordination of nose position with heading around the turn.

Could not really do a quick stop because of the excessive nose-down attitude necessary to gain much velocity. The crosswind turn was satisfactory and without overshoot or oscillation tendencies.

PILOT C PR = A2 M_δ = 0.80

Control sensitivity felt right.

The air taxi around the square was easy to perform. It was easy to initiate motion and hold a preselected rate of movement. Could stop precisely at the corners. No excessive attitude changes were required to initiate or control movement. Easy to hold heading.

It was fairly easy to remain over the spot on the ground in the turn over a spot. No excessive inputs to attitude were required. Could stabilize a preselected turn rate and stop on a preselected heading.

The crosswind turn was easy to accomplish. Could roll out on heading readily. No overshoot or undershoot tendencies. Very easy to establish heading. Control activity was minimal.

Precision hover was very good for a vertical landing. There was no excessive control activity.

CASE 150 (Continued)

Did not have a very fast forward velocity for the quick stop. Could stop quickly. No excessive attitude changes or overshoots. Control motions were minimal.

Height control was easy. There was poor harmony between lateral and longitudinal control which did affect the evaluation.

Damping was excellent.

[Because of the discrepancy in pilot ratings for the above two cases, the dynamic check runs made immediately prior to the flights were examined. They were identical.]

CASE 151

$X_u = -0.2$ $\lambda = 6.0$

$M_u g = 1.00$ $\omega_n = 0.41$

$M_q = -6.00$ $\zeta = 0.19$

$M_\theta = 0$

PILOT A PR = A3 $M_\delta = 2.00$

There was no tendency to oscillate even with the high control sensitivity selected.

An excessive attitude change to go forward into the wind was required.

Couldn't develop enough speed to properly evaluate the quick stop.

PILOT B PR = A6 $M_\delta = 1.36$

In the air taxi it was difficult to move into the wind and stabilize velocity. Substantial attitude changes were required in pitch.

Longitudinal response was abrupt. With the control sensitivity set higher, there was a tendency toward PIO.

Difficult to stay over the spot in the turn over a spot maneuver. Trouble killing drift. Could initiate turns and stop on a preselected heading.

Difficult to attain the spot in the crosswind turns. Precision of hover was only fair to poor but was adequate for a vertical landing. A lot of control activity. Difficult to get moving for a quick stop.

Height control required frequent collective inputs. Lateral dynamics felt loose and affected the rating some.

CASE 152

$X_u = -0.2$ $\lambda = 3.1$

$M_u g = 1.00$ $\omega_n = 0.57$

$M_q = -3.00$ $\zeta = 0.07$

$M_\theta = 0$

PILOT B PR = U8 $M_\delta = 0.83$

Control sensitivity selected was a little too high. Response was too abrupt. This may be a mechanical limitation on the simulator. Tendency to PIO.

Difficulty initiating and stabilizing forward motion. Response seemed to lag. Was not able to hover well at the corners of the square. Rudder response was sluggish and lacking in sensitivity. Could hold heading fairly well.

Pitch attitude was bothersome in the turn over a spot. Difficulty in hovering in all four directions. Could stop on preselected headings reasonably well.

Overshot in the crosswind turns. Tendency to move aft following turn. Hover difficult. Control activity was too high.

Couldn't get up any ground speed to speak of in the quick-stop maneuver. Overcontrolled when stopping, built up a PIO, and hit the stops.

Had height control problems throughout the evaluation. Lateral dynamics seemed squishy and degraded the evaluation.

PILOT C PR = U7 $M_\delta = 0.44$

Control sensitivity set at a level to compensate for the wind without large stick inputs.

Difficulty was experienced initiating motion into the wind or downwind. Difficulty holding a preselected rate of movement and stopping precisely. Excessive pitch attitude changes required. Rudder response was too low.

CASE 152 (Continued)

The turn over a spot required large pitch and roll changes. Crosswind turns worked out well without undershoots or overshoots. Moderate control activity was required to compensate for a constant oscillation in the longitudinal axis.

Could not get up a good forward velocity for the quick stop because of the excessive attitude changes required.

Height control and lateral directional dynamics did not affect the evaluation.

There was low to medium frequency oscillation which appeared to be not very well damped.

CASE 153

X_u	=	-0.2	λ	=	1.5
$M_u g$	=	1.00	ω_n	=	0.82
M_q	=	-1.00	ζ	=	-0.18
M_θ	=	0			

PILOT A PR = U7 M_δ = 0.92

Had to have too much nose-down attitude just to hold the airplane in the face of the wind.

Almost lost the airplane in an aft quick-stop maneuver. Required too much nose-down to stop the airplane and there was a tendency to pop up.

Great deal of difficulty overall. Hovering turn was very bad.

PILOT B PR = U9 M_δ = 0.79

Selection of control sensitivity was a compromise between a low value which seemed to result in a lag in response, and a high value which had a tendency to cause a PIO. Value chosen may have been on the high side.

Initiating forward motion in the air taxi was difficult. X_u seemed high and some M_u appeared to be present. Was not able to stabilize on a rate of movement. Could stop going forward but had a tendency to overshoot going aft. Hover was poor. There were excessive attitude changes in pitch required. Control feel was peculiar in the stick-forward, nose-down situation due to the weight of the stick.

Difficult to do a turn over a spot precisely.

The crosswind turn worked out reasonably well even including a hover.

Precision of hover was generally poor. Questionably adequate for a vertical landing. Control activity too high.

The quick-stop maneuver was reasonably good but could not achieve very much forward velocity.

CASE 153 (Continued)

Height control was somewhat of a problem. Lateral dynamics were a factor in the evaluation.

Had a tendency toward PIO. At times the airplane felt uncontrollable.

CASE 154

X_u	= -0.2	λ	= 1.2
$M_u g$	= 1.00	ω_n	= 0.93
M_q	= -0.30	ζ	= -0.37
M_θ	= 0		

PILOT A PR = A4-1/2 M_δ = 1.03

Couldn't fly the airplane smoothly. Had a lot of trouble maintaining position in the turn over a spot. Tendency to stop too soon in the quick stop.

Had to fly very carefully.

PILOT B PR = 10 M_δ = 0.67

(Pilot comments missing.)

CASE 154 (RERUN)

X_u	=	-0.2	λ	=	1.2
$M_u g$	=	1.00	ω_n	=	0.93
M_q	=	-0.30	ζ	=	-0.37
M_θ	=	0			

PILOT A PR = U7 H_δ Not recorded

Needed high value of control sensitivity to help eliminate pitching moment due to gust input. Too high a value resulted in a tendency toward PIO.

CASE 155

X_u	$= -0.2$	λ	$= 0.8$
$M_u g$	$= 0.33$	ω_n	$= 0.64$
M_q	$= -0.30$	ζ	$= -0.38$
M_θ	$= 0$		

PILOT A PR = A4 M_δ = 0.92

A control sensitivity higher than that selected resulted in overcontrolling, particularly in the crosswind turns.

Not too much nose-down attitude required to hover or move into the wind. Airplane was somewhat gust sensitive.

Quick stop fairly easy because of the ability to go ahead without excessive nose-down attitude.

PILOT C PR = A3 M_δ = 0.36

Easy to initiate motion in all directions in the air taxi around the square. Easy to stabilize and hold a preselected rate of movement. No difficulty in stopping precisely at the corners or in coming to a hover. No excessive attitude changes were necessary to perform any of the maneuvers. Rudder control was good, although it was not sensitive enough and lacked control power to match the longitudinal system.

Easy to maintain position in the turn over a spot. No difficulty making the small attitude changes required to maintain position. It was not difficult to initiate a turn or stabilize a preselected turn rate. Overshot several times in stopping on a preselected heading.

Tended to overshoot slightly in the crosswind turns but this did not cause excessive inputs in the longitudinal axis.

Control activity was moderate; control power adequate. In a precision hover it was easy to maintain position and a vertical landing would be very easy.

The quick-stop maneuver was performed with a fairly high airspeed. Could come to a stop quickly without overshoot or PIO tendency.

CASE 155 (Continued)

All motions were moderate throughout the flight. Height control did not make the maneuvers more difficult. Lateral dynamics did not affect the evaluation.

Slight jerkiness or lack of smooth response due to the frequency or damping. Control harmony was fair.

CASE 156

X_u = -0.05		λ = 1.2	
$M_u g$ = 0.33		ω_n = 0.52	
M_q = -1.00		ζ = -0.17	
M_θ = 0			

PILOT B   PR = A3 M_δ = 0.38

Control sensitivity selected may have been a little on the low side.

Could initiate and stabilize motion in the air taxi and stop fairly well. Able to hover very well at every corner of the square. Performance around the square seemed to be good. Workload was not heavy but a little less would have been desirable. Some difficulty making small precise inputs which would normally be made with pressure when a force gradient exists.

Small attitude changes required. M_u probably low; gusts not too disturbing.

Crosswind turns were performed fairly expeditiously. Precision of hover was good. Required moderate pilot effort.

Large attitude changes not required in the quick stop.

Altitude control was good. Airplane felt loose laterally, but control harmony fairly good.

PILOT C   PR = A2 M_δ = 0.36

It was easy to initiate motion in all directions in the air taxi, and easy to stabilize and hold a preselected rate of movement. There was no difficulty in stopping precisely and coming to a hover at the corners. No excessive attitude changes were required for any of the maneuvers. Could stay fairly close to the ground track.

Could stay close to the center in the turn over a spot. Attitude control was easy although there was slight over-controlling in pitch.

CASE 156 (Continued)

Crosswind turns worked out well. Could come to a hover immediately after making the turns. There was no tendency to overshoot or undershoot. Control activity was low to moderate.

In a precision hover the attitude was such that it would be excellent for a vertical landing.

Had a very high speed for the quick-stop maneuver, and stopped very quickly. There were no excessive attitude changes required and there was no tendency for pilot induced oscillations.

Height control did not make any maneuvers more difficult. Lateral directional and height dynamics did not affect the evaluation.

Response to control inputs was favorably quick.

CASE 157

X_u	=	-0.05	λ	=	2.1
$M_u g$	=	0.33	ω_n	=	0.39
M_q	=	-2.00	ζ	=	-0.03
M_θ	=	0			

PILOT B PR = A4 M_δ = 0.73

Able to initiate and stabilize motion easily in the air taxi around the square. Some difficulty hovering over a precise point. Control feel lacks the force gradient desired for small inputs.

Control was reasonably good in the turn over a spot. Could achieve good stabilization. Could maintain heading fairly well.

Height control was very good.

Control activity throughout was a little too high. Ability to hover was good.

PILOT C PR = A2 M_δ = 0.40

Pleasant to fly, easy to control, no tendency toward PIO, and very easy to perform the air taxi around the square. No difficulty initiating or stabilizing motion. Easy to stop precisely and come to a hover at the corners. There were no excessive attitude changes necessary to perform any of the maneuvers. Rudder control lacked adequate yaw rate.

No difficulty maintaining position in the turn over a spot. No excessive attitude changes were required.

In the crosswind turn there was some difficulty coming to a hover because of overshooting the turn due to the low yaw rate available. Control activity was low.

Precision hover was easy and would be excellent for a vertical landing.

CASE 157 (Continued)

Quick-stop maneuver was performed as quickly as desired without excessive attitude changes. Control activity was low.

Lateral directional and height dynamics did not affect the evaluation.

CASE 158

X_u	= -0.05	λ	= 1.0
$M_u g$	= 0.33	ω_n	= 0.58
M_q	= -0.60	ζ	= -0.28
M_θ	= 0		

PILOT A PR = A4-1/2 M_δ = 1.04

Ability to initiate motion was good, but a little difficult to stabilize. Had to raise the nose a little high to come to a halt.

The hovering turn was not difficult. In crosswind turns, considerable nose-up attitude was required to stop motion.

PILOT C PR = U8 M_δ = 0.23

Control sensitivity was kept low to avoid a jerky response. Damping was very poor. It was possible to fly the airplane as long as inputs were small and no violent maneuvers made.

It was easy to stabilize and hold a preselected rate of movement as long as the airspeed was held low and control movement kept small. Ability to stop precisely and come to a hover at the corners of the square was poor because of overshooting. No excessive attitude changes were required and it was easy to remain within the ground track.

It was easy to remain over a spot in the turn maneuver. Attitude control was fairly easy if control inputs were kept small. Easy to initiate a turn rate and hold a preselected rate though porpoising in the longitudinal axis required that the rate not get too large.

Crosswind turns were accomplished in a minimum amount of time. It was fairly easy to hold position over a point but there was some porpoising. Small control inputs tended to give rather large pitch changes.

Precision hover was easy as long as inputs were small.

The quick-stop maneuver resulted in a PIO which prevented stopping as quickly as desired. Heading was not affected but altitude control was affected.

CASE 201

Y_v	=	-0.05	λ	=	0.5
$L_v g$	=	-1.00	ω_n	=	1.51
L_p	=	-1.65	ζ	=	0.40
L_ϕ	=	-2.80			

PILOT A   PR = A2 L_δ = 2.00

Good control sensitivity. Airplane responded well to small stick movement. Slight tendency to oscillate.

Could control the airplane precisely in the air taxi around the square. Could stop precisely and hover at the corners.

The turn over a spot was good. Vertical landing could be made. The quick stop was satisfactory.

Longitudinal response was not as good as lateral.

PILOT B   PR = A4 L_δ = 0.85

Control sensitivity may have been a little high. Seemed to result in an oscillatory tendency.

Stabilizing motion around the square was only fair. Hover at the corners was not really solid. Lateral bank angles required were not large. Y_v is probably low. Damping did not seem very great. Tendency to oscillate. Rudder lacked sensitivity. Could hold heading fairly well.

The turn over a spot was fair, but had a tendency to overcontrol rather than undercontrol. Could maintain a constant rate turn.

Could come to a preselected heading in the crosswind turns, but the turning rates were not constant. Some difficulty when turning to a crosswind heading.

Crosswind turns were fairly good. Some difficulty coming to a precise hover.

Precision of hover was only fair but adequate for a vertical landing.

Quick stops were fairly good.

Height control was fairly good. Secondary dynamics had some influence on the evaluation.

CASE 202

$Y_v = -0.05$ $L_v g = -1.00$

$L_p = -1.05$ $L_\phi = -2.50$

$\lambda = 0.5$ $\omega_n = 1.50$ $\zeta = 0.20$

PILOT A PR = A2 $L_\delta = 1.14$

High control sensitivity made the response too oscillatory. The value selected was a little too high from that standpoint. A low value made the airplane sluggish.

Airplane was very easy to control in the air taxi around the square. Could hold the wings level in the crosswind. Had a slight tendency to oscillate in roll. Had no problem keeping within the ground track.

Turn over a spot was easy laterally. Longitudinal control required some attention.

The quick stop was easy. Could get up speed easily and stop easily. No tendency to overcontrol in the crosswind turns. Could control lateral oscillations easily.

PILOT C PR = A3½ $L_\delta = 0.42$

Control sensitivity selected was perhaps a little low. Lacked control power in the quick-stop maneuver.

No difficulty initiating motion in the air taxi around the square. No difficulty in stabilizing and holding the preselected rate of movement. Able to stop precisely and come to a hover at the corners easily. No excessive attitude changes were required. Ability to stay within the ground-track limits was fair. Rudder control response was low but adequate.

No excessive attitude changes were required in the turn over a spot. No difficulty remaining over the spot.

Crosswind turns were accomplished quickly. No tendency to overshoot or undershoot. There was no difficulty in establishing a hover over the correct position after the rollout and control activity throughout the turn was light to moderate.

Precision hover was easy to establish. No excessive attitude changes developed. Adequate for a vertical landing except for rather low damping. Oscillations were easy to damp out but it required pilot attention and was a little uncomfortable.

CASE 202 (Continued)

Could not perform a quick stop as quickly as desired. Control power was low.

Height control requirements did not make the maneuvers more difficult. Longitudinal dynamics did not affect the evaluation.

CASE 203

$Y_v = -0.05$ $L_v g = -1.00$

$L_p = -0.65$ $L_\phi = -2.30$

$\lambda = 0.5$ $\omega_n = 1.50$ $\zeta = 0.07$

PILOT A PR = A6 $L_\delta = 1.07$

Control sensitivity kept low because of low roll damping. Airplane is touchy to fly because of the roll control sensitivity.

Performance was good because it was not necessary to have the wing down into the wind. Airplane could develop PIO tendencies. A vertical landing could cause trouble.

The air taxi around the square wasn't bad. The turn over a spot was not difficult. Precision hover was easy. The crosswind turns were more trouble longitudinally than laterally. The quick-stop maneuver was satisfactory.

Special piloting technique was required because of low roll damping. Once the roll rate was started, the stick had to be moved in the opposite direction immediately. Had to lead the roll angle considerably to prevent the roll from building.

PILOT C PR = A5 $L_\delta = 0.42$

Control sensitivity was set to keep the response soft without jerkiness. Airplane has a tendency to overshoot.

No difficulty initiating motion in any direction in the air taxi around the square, or in holding any preselected rate of movement. Easy to stop precisely and come to a hover at the corners. No excessive attitude changes were required to compensate for wind or to perform the maneuvers. Could stay fairly close to the ground track. Rudder control response seemed crisp and was well-matched. Lateral dynamics required more damping.

The turn over a spot could be performed fairly close to the spot. Attitude control was easy although stick activity was fairly high due to a tendency to overcontrol.

The crosswind turn was performed without excessive time used. Slight tendency to overshoot. Control activity was slightly high.

Precision hover was easy and adequate for a vertical landing. Control activity was low to moderate although there was a PIO tendency.

The quick stop could be performed quickly after a fairly high translational speed. Control motions were moderate.

CASE 203 (Continued)

Height control was very easy. Longitudinal dynamics did not affect the evaluation.

Improvement is needed in damping and perhaps frequency.

CASE 204

	$Y_v = -0.050$		$L_{v}g = -1.00$
	$L_p = -1.95$		$L_\phi = -2.00$
	$\lambda = 1.0$	$\omega_n = 1.05$	$\zeta = 0.48$
PILOT A	PR = A5		$L_\delta = 0.31$

Lateral task was easier than the longitudinal. Tended to be slightly oscillatory. Tendency toward PIO.

Difficult to maintain good performance in the air taxi around the square and in the turn over a spot.

PILOT B	PR = A3		$L_\delta = 1.07$

Could perform the air taxi around the square fairly well. Could come to a good hover at the corners, though it was difficult to hold it for very long. Bank angle required throughout was fairly small. Pitch attitude changes were large. Hover was more difficult longitudinally than laterally.

Small control inputs were difficult to make because of the weight of the stick and lack of centering. Rudder response was adequate, though more sensitivity would be desirable. Heading — hold was good.

The turn over a spot was good. Could achieve a good hover in every direction. Hover was the most difficult downwind due to the nose-up altitude. Was able to stop at any heading adequately.

The crosswind turns were good. Could come to a reasonable hover. Some difficulty making small corrections. Hover was adequate for a vertical landing.

Some difficulty was experienced in the quick-stop maneuver with overshooting.

Height control caused some difficulty in the quick stop and crosswind turns. Otherwise, it did not require much effort.

Precision of control throughout was better laterally than longitudinally, but was still objectionable in a hover.

CASE 205

$Y_v = -0.05$ $L_v g = -1.00$

$L_p = -1.55$ $L_\phi = -1.60$

$\lambda = 1.0$ $\omega_n = 1.04$ $\zeta = 0.29$

PILOT B PR = A4 $L_\delta = 0.74$

Could perform the air taxi around the square reasonably well. Was able to stabilize motion. Some tendency existed to oscillate laterally. Could come to a good hover at the corners, but constant control activity was required. Attitude changes in roll were not excessive. Would prefer the rudder control to be more sensitive.

Could perform the turn over a spot reasonably well. Able to stabilize on the desired headings. Could initiate and maintain a turn rate quite well.

Performance in the crosswind turns was reasonable. Could establish a hover fairly precisely. Hover was certainly adequate for a vertical landing. Control activity was moderately high.

Precision of performance in the quick-stop maneuvers was fair. Coordination of height and attitude control was the biggest problem.

PILOT C PR = A3 $L_\delta = 0.43$

Some tendency to overcontrol laterally.

No trouble initiating motion and holding a preselected rate of movement in the air taxi around the square. Could stop precisely at the corners without overshoot. No excessive altitude changes were required.

No difficulty remaining over the spot in the turn over a spot. There were no excessive control movements. Rudder control was adequate. No difficulty stabilizing and holding a preselected turn rate or stopping at a preselected heading.

The crosswind turns were comfortable to perform. Could readily establish a hover after the turn. There were no overshoot or undershoot tendencies and there was no difficulty establishing a heading. No difficulty establishing a position over a preselected spot. Control activity was not excessive. The precision hover was adequate for a vertical landing.

A quick stop was easy to perform although there was a slight overshoot tendency. There were no excessive attitude changes required to perform the maneuver. Control motions were not excessive.

Longitudinal and height dynamics did not affect the evaluation.

Control harmony was fair.

CASE 206

Y_v = -0.05 $L_{v}g$ = -1.00

L_p = -1.15 L_ϕ = -1.20

λ = 1.0 ω_n = 1.03 ζ = 0.10

PILOT B PR = A6 L_δ = 0.87

Pilot comments not available.

PILOT C PR = A2 L_δ = 0.48

The air taxi around the square was easy to perform. Motion could be initiated and held at the desired speed with no difficulty. Stops could be made fairly close to the corners essentially without overshoot. Could stay fairly close to the ground track.

The turn over a spot could be performed close to the spot. Control harmony was good. Turn rates were initiated with ease and desired turn rates were held with no difficulty. Slight overshoot of the stop on a preselected heading was attributed to technique rather than control system deficiency.

Crosswind turns were accomplished expeditiously without overshoot or undershoot. Heading was established immediately upon rolling out of the turn and position was held over the desired spot. Control activity was light; control power adequate.

In the quick-stop maneuver the vehicle was stopped as quickly as desired without excessive attitude changes. Heading control was not difficult during the maneuver and height control was easy. Control motions were minimum.

[Because of the substantial difference in the pilot ratings of this case the dynamic check runs made immediately prior to each of the above evaluations were examined. They were found to be identical.]

CASE 207

	$Y_v = -0.05$		$L_v g = -1.00$
	$L_p = -2.25$		$L_\phi = -1.81$
	$\lambda = 1.5$	$\omega_n = 0.85$	$\zeta = 0.35$
PILOT B	PR = A4		$L_\delta = 0.77$

Large bank angles were not required. Some lag in lateral control response. Was able to maintain a rate of movement fairly well laterally. Ability to stop precisely was fair. Ability to remain within the ground track was fair.

Could perform the turn over a spot and stay within the 25-foot radius circle. Could initiate a turn rate reasonably well. Could stabilize on a preselected heading fairly well.

Crosswind turns were not performed as well as desired. There was some problem with altitude control.

Could reach a steady-state hover which was generally quite good. It was certainly adequate for a vertical landing. Fair amount of control activity.

The quick stops were not very good. Had height control problems.

Height control requires effort. Longitudinal dynamics affected the hover and the air taxi around the square. It added to the pilot workload.

PILOT C PR = A3 $L_\delta = 0.43$

There was a tendency for the response to lag slightly and be sluggish to lateral inputs.

No trouble initiating motion in any direction in the air taxi around the square. No trouble in stabilizing a preselected rate of movement. Easy to stop at the corners and come to a hover. No excessive attitude changes were required. Stayed fairly close to the ground track. Rudder control was adequate although the rate was lower than optimum. There was no difficulty in holding a heading at any time during the maneuvers.

Very little trouble staying over the spot in the turn over a spot.

Some tendency was present to overshoot or undershoot in the crosswind turns. Could readily come to a hover.

Control activity for the entire flight was moderate with a slight tendency to overcontrol in the lateral axis. There was little difficulty establishing and maintaining a precision hover. No extreme attitudes were developed. The hover was more than adequate for a vertical landing.

CASE 207 (Continued)

Could stop quickly in the quick-stop maneuver, but there was some tendency to overcontrol and overshoot laterally.

Height and longitudinal dynamics did not affect the evaluation.

CASE 208

$Y_v = -0.05$ $L_v g = -1.00$

$L_p = -1.85$ $L_\phi = -1.21$

$\lambda = 1.5$ $\omega_n = 0.84$ $\zeta = 0.24$

PILOT A PR = A2-1/2 $L_\delta = 1.48$

Control sensitivity set fairly high to get quick roll response. Airplane had a tendency to be a little oscillatory.

Airplane did not require wing-down to hold into the wind. Ability to initiate motion was very good laterally. Performance on the turn over a spot was very good because only the pitch attitude required much attention.

The crosswind turn resulted in a slight tendency toward oscillation. Would prefer more damping. The quick-stop maneuver was good because it was easy to get up motion and then to stop it due to the absence of excessive attitude changes.

PILOT B PR = A3 $L_\delta = 1.43$

Control sensitivity set to cut down on the abruptness of response. Performance would probably not be affected over a wide range of sensitivities.

Able to initiate motion fairly easily in any direction in the air taxi. Could stabilize the rate of motion and come to a stop at the corners quite well. No large attitude changes required. Ability to remain within the ground track was fair. Control felt good. Seemed to be some mismatch between longitudinal and lateral. Rudder control could well be more sensitive.

The turn over a spot was quite good throughout. Altitude control was good. Could initiate and stabilize on the turns well.

Crosswind turns were good. Some tendency to overshoot longitudinally. Airplane not too much affected by lateral winds and gusts, thus could fly fairly wings level. Some slight tendency to bobble laterally. Roll damping seemed pretty good.

Could come to a good precision hover with only moderate effort. Control activity was just modest.

Quick stops were good though there was some overshoot. Altitude control activity was small.

No really strong objectionable features.

CASE 209

$Y_v = -0.05$	$L_v g = -1.00$
$L_p = -1.45$	$L_\phi = -0.61$
$\lambda = 1.5 \quad \omega_n = 0.83$	$\zeta = 0$

PILOT A $\quad$ PR = A3 $\quad$ $L_\delta = 1.41$

A very good airplane to fly except for a tendency to roll with side gusts. Otherwise there was no tendency to oscillate in roll and the wings could be held level in the winds.

Easy to initiate motion in the air taxi. Very easy to hold the airplane over a spot except for an annoying lateral upset with gust input. Could remain within the ground track without a great amount of control movement. The longitudinal characteristics were not as good as the lateral.

The turn over a spot was more difficult in the longitudinal axis than the lateral. Rudder control was adequate.

The quick stop was easy without any tendency to oscillate or overshoot. Crosswind turn was also rather easy. No danger of losing control.

PILOT C $\quad$ PR = A5 $\quad$ $L_\delta = 0.61$

Control sensitivity was turned up to a point where small stick corrections would compensate for a tendency to oscillate laterally.

There was no difficulty initiating motion or stabilizing a preselected rate of movement in the air taxi around the square. There was some trouble in stopping precisely at the corners although once in the hover it was easy to maintain a hover. No excessive attitude changes were required in pitch or roll. Could stay fairly close to the ground track. Rudder response was slow.

The turn over a spot was easy to perform and to stay close to the spot.

The crosswind turns resulted in overshooting and undershooting due to slow rudder response. There was some difficulty establishing a heading, but once established it was very easy to hold. Control activity was light to moderate. Most inputs were used to damp out the lateral oscillation.

A precision hover was easy to establish. There were no excessive attitudes or angular rates. Could perform a vertical landing. Could possibly develop a PIO with large inputs.

Could perform a quick stop without excessive attitude changes. No difficulty in holding heading or altitude.

Height control was easy. Longitudinal dynamics did not affect the evaluation.

CASE 210

$Y_v = -0.05$ $L_v g = -1.00$

$L_p = -3.15$ $L_\phi = -2.03$

$\lambda = 2.5$ $\omega_n = 0.66$ $\zeta = 0.53$

PILOT A PR = A1-1/2 $L_\delta = 2.00$

Control sensitivity selected may have been a little high.

Airplane was dead beat in roll and did not respond to gusts. Required a slight wing-down attitude to hold position into the wind.

Air taxi around the square, the turn over a spot, precision hover, crosswind turn, and the quick stop all could be performed well and with ease.

PILOT C PR = A2 $L_\delta = 0.62$

Control sensitivity may have been selected a little high. May have been able to fly the ground track closer with a lower value that matched the longitudinal system.

In the air taxi around the square it was easy to initiate motion in every direction and easy to hold a preselected rate of motion. No difficulty in stopping precisely at the corners and coming to a hover. No excessive attitude changes were necessary for any of the maneuvers. Rudder control response seemed slow and sluggish.

Stayed fairly close to the center in the turn over a spot. No problem with altitude control.

Crosswind turns were accomplished fast without overshoot or undershoot tendencies. There was no difficulty establishing heading or position over the spot after completion of the turn. Control activity was light.

It was very easy to establish and maintain a precision hover. There were no excessive attitudes required and the airplane would be excellent for a vertical landing.

Did not stop as quickly as desired in the quick-stop maneuver due to overshooting. No excessive attitude changes were required and there was no difficulty in holding heading or altitude. Control motions were light to moderate.

Height control requirements did not make the maneuvers more difficult. It was easy to maintain altitude within one or two feet.

Longitudinal dynamics did affect the evaluation because control harmony was so poor that it detracted from the lateral system's capabilities.

CASE 211

$Y_v = -0.05$ $\lambda = 2.50$

$L_v g = -1.00$ $\omega_n = 0.65$

$L_p = -2.75$ $\zeta = 0.23$

$L_\phi = -1.03$

PILOT B PR = A4 $L_\delta = 1.64$

Could stabilize velocity fairly well. Attitude was fairly level laterally indicating low Y_v. Ability to hover was fair. More difficulty longitudinally than laterally. A little difficulty with height control.

Could stay over the spot fairly well in the turn over a spot. Able to stop on headings quite well. Hover was fair.

Could stop a crosswind turn fairly well over the spot. Overshot a little. Hover adequate for a vertical landing.

Could perform all the maneuvers reasonably well.

PILOT C PR = A4 $L_\delta = 0.38$

Control sensitivity was set low to prevent abrupt response to control input. Slight tendency to overcontrol in lateral axis.

In the air taxi around the square there was no difficulty initiating motion but a little difficulty stabilizing a preselected rate of movement. A little difficulty coming to a precise hover due to overcontrolling.

No difficulty remaining over the spot in the turn over a spot. Attitudes were never extreme. Only small changes were needed to correct for wind.

Overshot slightly in the crosswind turns due to the overcontrol tendency in the lateral axis carrying over into the longitudinal. No difficulty establishing a heading after the turn. Control motions in the lateral axis were moderate. Vehicle would be very good for a vertical landing.

CASE 211 (Continued)

Stopped quickly in the quick-stop maneuver with no excessive attitude changes required. No difficulty holding heading or altitude. Control motions were light to moderate.

Height and longitudinal dynamics did not affect the evaluation. Height control did not make the maneuvers more difficult.

CASE 212

Y_v	= -0.05	λ	= 2.50
$L_v g$	= -1.000	ω_r	= 0.64
L_p	= -2.45	ζ	= 0
L_ϕ	= -0.28		

PILOT A PR = A2 $L_\delta = 1.56$

Control sensitivity higher than that selected resulted in an inadvertent rolling oscillation.

Airplane did not require wing-down into the wind to hold ground position. There was no noticeable gust response.

The longitudinal characteristics caused more difficulty than the lateral, both in the air taxi and the turn over a spot.

Precision hover was very easy because the airplane stayed pretty much in position with the wings level.

The quick stop was very easy. Could get a lot of speed up. With the wing-up to stop, the airplane seemed to coast a considerable distance. Would have desired a little more drag to help stop. No problem in overcontrolling in spite of a tendency to oscillate.

The crosswind turn was no problem laterally but there was some difficulty longitudinally coming to a stop.

PILOT C PR = A3 $L_\delta = 0.56$

Control sensitivity was set to give a fast response. Airplane was easy to fly and had no serious deficiencies.

There was no difficulty initiating motion in the air taxi around the square. It was easy to stabilize a preselected rate of movement and very easy to stop precisely and come to a hover at the corners. No excessive attitude changes were necessary and it was very easy to keep close to the ground-track limits.

Slight overcontrolling laterally occurred in the turn over a spot. Attitude control was good. There was fairly good control harmony.

CASE 212 (Continued)

Crosswind turns were easy to perform, though there was a tendency to overshoot. There was no difficulty in establishing heading or position after the turn. Control activity was light.

Precision hover was very easy to establish and maintain and was very adequate for a vertical landing.

Could stop quickly in the quick-stop maneuver. Had a high translational rate. Overshot in rolling out of the maneuver. Control motions were moderate.

Height control was easy. Longitudinal dynamics did not affect the evaluation.

Airplane may have been neutrally stable but the period was so long that it was easy to control. Wouldn't diverge but just didn't damp out well by itself.

CASE 213

Y_v = -0.05 λ = 6.0

$L_v g$ = -1.00 ω_n = 0.43

L_p = -6.35 ζ = 0.47

L_ϕ = -2.27

PILOT A PR = A2 L_δ = 2.00

Needed high control sensitivity to get good response with stick displacement. Response was a little slow but comfortable.

In the air taxi just a small amount of wing-down was needed to hold into the wind. As a result, control was very easy. There was no tendency to roll due to gust input. Airplane was very stable. Performance on the square pattern could have been better. With practice the airplane could be flown very precisely.

The turn over a spot was very easy to fly. Precision hover was very easy once the small amount of wing-down necessary was determined.

The quick stop was very easy. Did not need much wing-down to accelerate laterally. Excessive attitude changes were not required.

The crosswind turn was easy because of the well-damped roll response. No tendency to oscillate or respond to gusts.

PILOT C PR = A1-1/2 L_δ = 0.81

Control sensitivity was set to keep the stick movement down to a reasonable value.

There was no difficulty with any of the maneuvers in the air taxi around the square.

There were no excessive attitude changes required in either the pitch or roll axis while turning over a spot. Rudder response was slow.

The crosswind turn was easy to accomplish and it was easy to bring the vehicle to a hover after completing the turn. Overshot once due to low response from the rudders. Control activity was light and control power was adequate.

CASE 213 (Continued)

The precision hover was easy and would be very good for a vertical landing.

Could stop quickly with no excessive attitude changes in the quick-stop maneuvers.

Height control was very easy. Longitudinal dynamics did not affect the evaluation.

Did not find any objectionable features.

CASE 214

$Y_v = -0.05$ $\lambda = 6.0$

$L_{v\delta} = -1.00$ $\omega_n = 0.42$

$L_p = -6.15$ $\zeta = 0.24$

$L_\phi = -1.07$

PILOT B PR = A3 $L_\delta = 2.00$

Pilot comments not available.

PILOT C PR = A2 $L_\delta = 0.43$

Pleasant to fly. No tendency toward PIO.

The air taxi was simple to perform with no excessive control inputs required. Could hold a preselected rate of movement easily and there was no problem stopping precisely at the corners. Attitude changes were small. Could stay within the ground track easily. Rudder control was adequate and control harmony was excellent.

There was no difficulty turning over a spot and no excessive pitch or roll changes throughout the turn. Turn rates were easily initiated and held at a preselected rate without difficulty. There was no problem stopping on a preselected heading.

Crosswind turns were easy to perform with no excessive time used to control the vehicle or put it over a point on a heading. There were no overshoot or undershoot tendencies. Control activity was light to moderate and control power more than adequate.

Precision hover was easily performed and control was ample for a vertical landing.

Vehicle could be stopped quickly without excessive attitude changes in the quick-stop maneuver if desired, though full lateral control with a steeper attitude was used for the stop without difficulty. There was no trouble holding heading or altitude throughout the maneuver and control motions were not excessive.

Longitudinal and height dynamics did not affect the evaluation. There were no objectionable features.

CASE 215

Y_v	= -0.05	λ	= 6.0
$L_v g$	= -1.00	ω_n	= 0.41
L_p	= -5.95	ζ	= 0.02
L_ϕ	= 0		

PILOT A PR = A3 L_δ = 2.00

Airplane meets the requirements of an A3 airplane in the lateral axis.

PILOT B PR = A2 L_δ = 2.00

Control sensitivity selected was good enough that all the tasks could be performed quite well. A higher sensitivity might have been even better.

Could do everything in the air taxi around the square with good precision including the initiation of motion, stabilizing, establishing heading, coming to a stop, and hovering at every corner. Ability to remain within the ground track was pretty fair. Limited on the preciseness of small control inputs. This is perhaps a resolution problem on the control.

There was some difficulty staying over the spot in the turn over a spot due to the crosswind and visibility but generally it was pretty good. Able to stop on a preselected heading.

The crosswind turns were quite good. Could come to a hover very readily once a heading was established. Control activity was moderate.

Precision of hover was very good. Might have been even better with centering springs and trimming capability. Certainly adequate for landing. Control activity was relatively light.

The quick-stop maneuver was okay. Had some difficulty with height control.

Longitudinal dynamics were not as good as the lateral. The aircraft was quite level in the wind. No oscillatory tendencies, even with the high control sensitivity, were evident.

CASE 216

$Y_v = -0.05$ $\lambda = 3.1$

$L_v g = -1.00$ $\omega_n = 0.57$

$L_p = -3.00$ $\zeta = -0.05$

$L_\phi = 0$

PILOT A PR = A2 $L_\delta = 1.78$

Control sensitivity was set perhaps a little high to compensate for what seemed to be a lag in the lateral response to control input. Laterally the airplane did not need wing-down to compensate for the wind.

Could hold a preselected rate of movement in the air taxi around the square. No excessive attitude changes were required laterally. Relatively, the longitudinal attitude changes were excessive. Laterally, it was easy to fly the ground track.

The turn over a spot was no trouble laterally at all. Pitch attitude changes caused some difficulty.

The quick stop was very good. Could pick up speed easily and stop where desired.

The crosswind turn was very good but required careful regulation of pitch attitude when turning into the wind.

PILOT B PR = A3-1/2 $L_\delta = 1.72$

The control sensitivity chosen might have been a little less. With the value selected there was a tendency to overcontrol laterally. Response was rapid and jerky. Perhaps there was a slight tendency for the pilot to keep an almost constant small amplitude oscillation going.

This was possibly caused by the high sensitivity chosen and perhaps by the aircraft dynamics, also. The precision of lateral control was pretty good, however. The aircraft was fairly level; there was perhaps some amount of response to the sidewind. Had more trouble longitudinally than laterally.

Was able to initiate motion quite reasonably in the air taxi and stabilize the motion. Able to stop where desired and hover fairly well. There seemed to be a lag in the response going to the right, but all in all it wasn't too bad. Had a little more difficulty with the longitudinal than the lateral. Lateral attitudes did not require as much change as the longitudinal.

CASE 216 (Continued)

Did not have much trouble holding heading.

Did reasonably well maintaining the turn over a spot. Could stabilize in a hover readily and there was no difficulty with rudder control.

Had no trouble lining up and maintaining lateral displacements following the crosswind turns but did have quite a bit of trouble sliding fore and aft. Control activity was moderate.

Overshot in the quick stops but otherwise they were not bad. Could hover readily and height control was no trouble.

Longitudinal control definitely affected the overall rating. Cannot help but be influenced by it.

There is a slight bank angle required to offset wind but it is not really bad. Could learn to reduce the lateral PIO with more practice.

CASE 217

$Y_v = -0.05$ $\lambda = 2.2$

$L_v g = -1.00$ $\omega_n = 0.68$

$L_p = -2.00$ $\zeta = -0.12$

$L_\phi = 0$

PILOT B PR = A5 $L_\delta = 0.79$

Precision of control in the air taxi around the square was not very great. Lack of friction or springforce in the stick affects the precision of control. Could stabilize heading with concentration and come to a stop reasonably well. Trouble establishing a hover. Effort expended was too great. Rudder control should be a little more responsive. Airplane was rather sluggish in yaw.

In the turn over a spot, the hover was poor at the four headings. Pitch attitude was a bigger problem than bank angle.

The crosswind turns were surprisingly good. Could reach a stabilized hover which was adequate for a vertical landing.

Quick stop was accomplished rather easily. No large attitude changes were required. Could hold heading reasonably well. Control motions were mild. Height control was all right.

Bank angle required to offset the crosswind seemed to be fairly small. Y_v is probably small. Overall precision of performance was not as good as desired; a nervous type of airplane. This may have been caused by a lateral control sensitivity which was a little high. This may have caused some overcontrolling.

PILOT C PR = A5 $L_\delta = 0.43$

An increase in the control sensitivity from that selected made the response too jerky. Was unable to make turns or hover in a crosswind with any less sensitivity, however.

Able to stay fairly close to the ground track in the air taxi around the square. Some overcontrolling laterally. Not much difficulty stopping at the corners although there was some overcontrolling laterally establishing a hover.

Stayed fairly close to the spot in the turn over a spot. Attitude was never excessive. The crosswind turn worked out well but with some delay in getting established over the position. Control

activity was moderate to heavy.

In the precision hover there were no excessive attitudes or angular rates developed. The attitude was adequate for a vertical landing.

Stopped as quickly as desired in the quick-stop maneuver. Did not feel any tendency toward pilot-induced oscillations even after full lateral stick input.

Height control requirements did not make the maneuvers more difficult. Longitudinal and height dynamics did not affect the overall evaluation.

Response in the lateral axis seemed sloppy.

CASE 218

Y_v = -0.05 λ = 1.5

$L_v g$ = -1.00 ω_n = 0.82

L_p = -1.00 ζ = -0.26

L_ϕ = 0

PILOT B PR = A5 L_δ = 0.79

Hover was fair to good but it required work. Had as much trouble longitudinally as laterally in the hover.

Crosswind turns were pretty bad. Got into a lot of oscillation.

PILOT C PR = A3 L_δ = 0.64

Airplane was comfortable and easy to fly. Control sensitivity was turned up to give a crisp response. Made the response slightly abrupt but not enough to be unpleasant or cause any difficulties. With the sensitivity turned down, the hover would perhaps be like a big bomber or transport.

During the air taxi around the square the motion was maintained easily and at the desired rate. There was no difficulty stopping precisely at the corners and there were no excessive attitude changes required to perform the maneuver. Stayed fairly close to the desired ground track.

The turn over a spot was performed with no difficulty and without excessive pitch or roll attitude changes. Ability to initiate the turn was normal and a preselected rate was easy to hold. There was no tendency to overshoot or undershoot the headings.

The crosswind turns were performed readily. Very little correction was needed after the maneuver was completed. There was no tendency to overshoot or undershoot. Headings and position were established immediately upon rolling out. Control activity was light to moderate.

Precision hover was easy to maintain. Gusts did not seem to affect the vehicle excessively.

CASE 218 (Continued)

The quick stop was easy to perform without excessive control inputs or attitude changes.

Height control did not affect the evaluation or make the maneuvers more difficult.

Dynamics seemed quite well-matched for this vehicle.

CASE 219

Y_v	$= -0.05$	λ	$= 1.1$
$L_v\ g$	$= -1.00$	ω_n	$= 0.94$
L_p	$= -0.30$	ζ	$= -0.41$
L_ϕ	$= 0$		

PILOT A PR = A5 $L_\delta = 1.80$

For the control sensitivity selected there was an annoying tendency toward pilot-induced oscillations in roll.

There was no problem initiating motion in the air taxi around the square. Could stabilize motion fairly well but stopping motion was not as good as desired. Attitude changes were small. No difficulty with rudder control.

The turn over a spot wasn't too bad, although once a side velocity developed the ability to stop it was not good.

Precision hover was not bad. Adequate for a vertical landing.

Could not perform a quick stop as quickly as desired. Airplane continued to skid even with considerable bank angle.

PILOT B PR = 10 $L_\delta = 1.21$

The control sensitivity was a compromise between a value high enough to stop oscillations quickly when they occurred and low enough to avoid inadvertently continuously oscillating the aircraft. The aircraft was dynamically unstable laterally and for large amplitude maneuvers, quickly applied control could result in real trouble. To do anything quickly would result in a PIO with the chances being that the aircraft would be lost. So it's a dangerous airplane.

Could initiate motion in the air taxi and stabilize the rate. Able to stop fairly well at the corners but the hover was not solid. Quite a bit of control activity. Feeling of looseness in the ability to stop the aircraft. Did not appear to be any excessive attitude changes required. However, occasionally there were pilot-induced inputs which were much too large. Had to do everything slowly to avoid getting into trouble. Rudder control was okay.

CASE 219 (Continued)

The turn over a spot was fairly good except for the annoying oscillation all the way around. Could do a reasonable job of staying over the spot and coming to a loose hover with concentration.

Got into the lateral oscillation in the crosswind turns. Hover was poor but adequate for a vertical landing. Considering the divergent oscillation the hover was surprisingly good. Control activity, however, was appreciable.

Got into a divergent oscillation in the quick-stop maneuver and hit the simulator stops.

Height control was not too bad except in the quick stops. Secondary dynamics did give trouble then. Airplane did not seem to be very sensitive to lateral gusts and was fairly level. Airplane is rated uncontrollable due to losing it twice. Most of the maneuvers would be around an A6 or a U7.

CASE 220

$Y_v = -0.2$		$\lambda = 0.3$
$L_v\,g = -0.33$		$\omega_n = 1.91$
$L_p = -2.10$		$\zeta = 0.52$
$L_\phi = -3.84$		

PILOT B   PR = A5 $L_\delta = 1.31$

Control sensitivity chosen may have been a little high. There was some tendency to get into a lateral PIO.

Could stabilize velocity fairly well in the air taxi around the square. Could stop fairly well but it took a fair amount of effort to establish a hover. Gusts were bothersome.

Stayed close to the desired position in the turn over a spot. Bank angles were a little high and were bothersome in establishing a good steady hover. Had to work too hard. Could stabilize a yaw rate fairly well.

Performance in the crosswind turns was fair. Hover was pretty good. Could start a landing. Pitch attitude change to stop on the spot was large.

Initiation of motion for the quick stops was fairly good. Drifted somewhat in coming to a stop. Precision of hover was not great. Bank angles to kill drift were bothersome.

Workload required for reasonable precision in performing the maneuvers was high.

PILOT C   PR = A4-1/2 $L_\delta = 0.60$

Control sensitivity set to give adequate acceleration to control the vehicle.

The air taxi around the square was a little sloppy because of the necessity to make large lateral inputs to correct for wind. There was no problem in stabilizing and holding a preselected rate of movement and not too much difficulty in coming to a hover at the corners. The roll attitude change to correct for wind was excessive in the hover and in the turn over a spot. However, fairly close position over the spot on the ground could be maintained in the turn.

CASE 220 (Continued)

The crosswind turns worked out quite well. There was no tendency to overshoot or undershoot. Control activity was moderate. Control power was adequate but could have been increased slightly.

The precision hover was adequate for a vertical landing.

Quick stops required excessive attitude changes. There was no problem holding altitude. Control motions were moderate.

Height and longitudinal dynamics did not affect the evaluation.

CASE 221

Y_v =	-0.2	λ =	0.3
$L_v\, g$ =	-0.33	ω_n =	1.87
L_p =	-1.30	ζ =	0.32
L_ϕ =	-3.60		

PILOT A PR = A4-1/2 L_δ = 1.83

Could tolerate a high control sensitivity because of good damping in roll.

The air taxi around the square had the principal objectionable feature of too much wing-down into the wind.

Had trouble with lateral drift in the turn over a spot.
The quick stop was a rather difficult maneuver because of the large amount of wing-down to get up a reasonable velocity. The crosswind turn was not difficult but was performed sort of sloppily.

PILOT C PR = A6 L_δ = 0.75

Control sensitivity had to be increased to an uncomfortable level in order to keep stick movements to an acceptable level and overshooting in the lateral axis was induced. Did not feel that there was a tendency toward pilot-induced oscillations.

In the air taxi around the square there was some difficulty in stabilizing and holding a preselected rate of movement due to the steep bank angle necessary to compensate for crosswind. This also made it difficult to stop precisely and come to a hover at the corners of the square, and to remain within the ground-track limit. The turn over a spot was a difficult maneuver. Did not remain over the spot. Attitude control in the roll axis seemed to be the cause.

The crosswind turns worked out well except for some tendency to overcontrol laterally after the rollout. Control activity was moderate to high.

The precision hover required such a large attitude correction to correct for prevailing wind that it would be difficult to land the vehicle. Ground effect could actually make this vehicle unflyable.

Stopped quickly in the quick-stop maneuver but did not have a very large translational speed because of the steep attitude required to generate this speed. Control motions were moderate.

CASE 221 (Continued)

Height control requirements did not make the maneuvers more difficult. Longitudinal and height dynamics did not affect the evaluation.

CASE 222

Y_v	$= -0.2$	λ	$= 0.3$
$L_v\, g$	$= -0.33$	ω_n	$= 1.82$
L_p	$= -0.30$	ζ	$= 0.06$
L_ϕ	$= -3.30$		

PILOT A PR = A5 $L_\delta = 1.38$

Control sensitivity selected seemed adequate, but was not entirely satisfactory. Had some trouble with roll oscillation.

The air taxi around the square required too much wing-down into the wind. Excessive attitude change was required in roll to stop movement upon completion of the downwind leg of the square.

The turn over a spot was difficult because of the wing-down attitude and the oscillation in roll. The large amount of wing-down made it difficult to hover precisely.

Did not seem to have too much trouble in the crosswind turns although there was a tendency to oscillate in roll upon rolling out. The quick-stop maneuver was very unsatisfactory. Could not get up enough velocity into the wind to really evaluate a quick stop.

There was so much difficulty with the lateral-directional dynamics that there was a tendency to ignore the longitudinal dynamics.

PILOT C PR = U7 $L_\delta = 0.61$

Vehicle was rather difficult to fly because of the steep attitudes required, a tendency to overcontrol and a feeling that it would be possible with the right inputs to initiate a PIO.

Had trouble initiating motion in the air taxi around the square particularly when going backwards with the wing down. Once in motion it was easy to stabilize and hold the preselected rate. Had difficulty in stopping precisely at the corners and coming to a hover. There were excessive attitude changes in the roll axis. Had difficulty remaining within the ground track because of the large attitude corrections necessary and also the large lateral inputs made trying to damp out the oscillations.

CASE 222 (Continued)

Had difficulty remaining over the spot in the turn over a spot because of the steep attitudes necessary to control the vehicle. The crosswind turns worked out well although it took too much time to come to a hover. There was no difficulty in establishing heading. Control activity was heavy. Control power was perhaps too high and caused some of the overcontrolling.

A precision hover was fairly easy to hold although the vehicle seemed very susceptible to gusts and would be very difficult to use in a vertical landing. The quick stop worked out well, stopped quickly. Excessive attitude change was required to initiate motion over the ground.

Height control throughout was difficult because of the constant control inputs. The lateral dynamics did affect the control of the longitudinal but probably not vice versa.

CASE 223

$L_v = -0.2$ $\lambda = 0.5$

$L_v g = -0.33$ $\omega_n = 1.12$

$L_p = -1.30$ $\zeta = 0.45$

$L_\phi = -1.50$

PILOT B PR = A5 $L_\delta = 0.72$

Could perform a good hover. Had more trouble longitudinally than laterally. Turn over a spot was not bad. Had the feeling that it took more bank angle to kill the drift in a left bank than in a right bank.

The crosswind turns were fair to good. In the quick-stop maneuver there was some overshooting.

PILOT C PR = A6 $L_\delta = 0.51$

Airplane was moderately difficult to fly. Control sensitivity was selected to give adequate response to correct for gusts.

In the air taxi around the square there was no trouble initiating motion or holding a preselected rate of movement. Had quite a bit of trouble stopping precisely and coming to a hover at the corners. Attitude changes in roll were slightly high. Was rather erratic in remaining within the ground-track limits.

The turn over a spot worked out fair although the control inputs were excessive. Had tendencies to overcorrect and get into pilot-induced oscillations.

The crosswind turn maneuver took quite a bit of time to accomplish and to come to a hover after completing the turn. There was no difficulty in establishing a heading after rolling out. Control activity was high. Control power was adequate.

The precision hover was adequate for a vertical landing. Control activity in hover was high.

A very large attitude change was required in the quick-stop maneuver. Overshot three or four times before coming to a stop. Control motions in this maneuver were very high.

CASE 223 (Continued)

Height control requirements did not make the maneuvers more difficult although height control was very erratic due to overcontrolling in the lateral axis.

Lateral response to control input was rather slow.

CASE 224

$Y_v = -0.2$ $\lambda = 0.5$

$L_v g = -0.33$ $\omega_n = 1.08$

$L_p = -0.80$ $\zeta = 0.23$

$L_\phi = -1.25$

PILOT A PR = U7 $L_\delta = 1.28$

Required too much wing-down to hover in a crosswind. There was a tendency to overcontrol into the wind and to oscillate about the wing-low position. Lost control during the turn over a spot due to attempting to control too tightly. Was not a bad airplane aside from the bad wing-down attitude.

PILOT B PR = U7 $L_\delta = 0.94$

This was a poor configuration because of the large bank angle required to maintain zero drift in a crosswind and because of a definite oscillatory tendency. The control sensitivity was chosen primarily because of this oscillatory tendency and a tendency to overcontrol if a higher value were chosen. Value chosen might have been on the low side.

Ability to stabilize motion in the air taxi around the square was fair to poor. Was not really able to stop precisely. Hover at the corners was poor. Required quite a bit of control activity. Attitude changes required were fairly large. Ability to remain within the ground track was fair to poor. Would prefer to have some sort of force feedback and centering springs in the controls. Rudder response was reasonable.

The turn over a spot was rather poor. Attitude control was difficult. The crosswind turns were fair but the ability to establish a hover was poor. Control activity was fairly high. It was excessive. Precision at hover was probably adequate for a vertical landing.

The quick stops were surprisingly good although there was some overshooting and the speed was not very high. Hover was decent and control motions required were moderate.

There were height-control problems and the longitudinal dynamics did enter into the evaluation somewhat. The oscillatory tendency was not divergent.

CASE 225

$Y_v = -0.2$ $\lambda \approx 0.5$

$L_v g = -0.33$ $\omega_n = 1.03$

$L_p = -0.30$ $\zeta = 0$

$L_\phi = -1.00$

PILOT A PR = A4 $L_\delta = 1.41$

The control sensitivity was set up to a point where a little pressure on the stick, almost without moving it, would pick up a wing in a manner similar to a conventional airplane. Noticed a slight tendency to oscillate in roll.

The air taxi was a little difficult because of the necessity to hold wing-down into the wind. The necessity to coordinate both lateral and longitudinal attitudes detracted from the performance in the turn over a spot. Could not move into the wind as readily to the left as when facing in the opposite direction and moving right.

Could not get up much velocity moving into the wind but it was easy to stop. A quick stop downwind, conversely, was more difficult.

The longitudinal dynamics did not detract from the lateral. The behavior was similar.

The airplane had very light damping in roll but this was not undesirable because a wing could be picked up by pressuring the stick.

PILOT C PR = U8 $L_\delta = 0.51$

Control sensitivity was set so that the stick movement was not too large to give the high bank angle necessary to compensate for the wind.

Had difficulty initiating motion and maintaining the preselected movement in the air taxi around the square. Had extreme difficulty in stopping precisely and coming to a hover at the corners. Excessive attitude changes were necessary in the lateral axis and there was also a tendency to overcontrol longitudinally because of the large inputs laterally. Had difficulty remaining within the ground-track limits.

CASE 225 (Continued)

Had difficulty remaining over the spot in the turn over a spot because of the extreme attitude changes necessary and the definite tendency to overcontrol. Response was very fast.

Crosswind turns were easy to accomplish except for coming to a hover over the spot after the turn. Control activity was heavy. No tendency to overshoot heading but a definite tendency to overshoot bank angle. Precision hover was difficult and control activity excessive.

Could stop quickly in the quick-stop maneuver but the simulator hit the stops. There would be a possibility of losing control and crashing in performing that maneuver in an airplane.

Height and longitudinal dynamics did not affect the evaluation but both caused some difficulty.

CASE 225 (RERUN)

Y_v	=	-0.2	λ	=	0.5
$L_v g$	=	-0.33	ω_n	=	1.03
L_p	=	-0.30	ζ	=	0
L_ϕ	=	-1.00			

PILOT A PR = A5 L_δ = 0.98

Control sensitivity could have been perhaps a little higher but it was very close to optimum. Control response lagged a little to stick input. Once the airplane started to bank it built up in a hurry and aileron had to be reversed to prevent it from building too quickly.

The air taxi around the square required quite a bit of wing-down to hold into the wind. There was a slight oscillating tendency while flying the square pattern and also in the crosswind turns. The turn over a spot was bad due to coordination of the excessive attitude changes in roll.

Surprisingly, was able to get up pretty good speed into the wind for the quick stop. There was a tendency toward lateral PIO when performing the stop.

CASE 226

Y_v	$= -0.2$	$\lambda =$	1.0
$L_v\, g$	$= -0.33$	$\omega_n =$	0.76
L_p	$= -1.80$	$\zeta =$	0.67
L_ϕ	$= -1.21$		

PILOT A   PR = A4-1/2 L_δ = 2.00

Chose a high control sensitivity to cut down stick movement. Airplane required objectionable wing-down into the wind.

Difficult to initiate motion into the wind in the air taxi around the square. Airplane had a tendency to wallow in sideward motion. Had trouble stopping precisely at the corners and hovering. Tendency to overshoot. Tendency to be sloppy about remaining within the ground-track limits.

The turn over a spot also was sloppy. Precision hover was satisfactory once in position. Airplane was not overly sensitive to gusts. Crosswind turns were performed reasonably well.

PILOT C   PR = A5 L_δ = 0.53

Control sensitivity set to have enough control to counteract for wind and gusts.

Ability to initiate motion in the air taxi around the square was average. Had difficulty holding a preselected rate of movement because of a slight tendency to overcontrol laterally. No excessive attitude changes were required. Ability to remain within the ground track was fair to poor. A great deal of attention was required just to control the vehicle.

Remained close to the 25-foot circle in the turn over a spot but was a little erratic. Pitch and roll were both factors in making it difficult to maintain position. Rudder control response felt slow.

Overshot on the crosswind turns and took excessive time to come to a hover and complete the turns. Control activity was moderate in the precision hover. Once established, the hover was adequate for a vertical landing. No steep attitudes were encountered. Control activity was moderate to slightly heavy.

CASE 226 (Continued)

Stopped quickly in the quick-stop maneuver but overshot several times.

Height control did not make the maneuvers more difficult but some trouble with height was experienced because of erratic inputs in the longitudinal axis Longitudinal dynamics were definitely a factor in the overall control, if not in the evaluation.

CASE 227

Y_v = -0.2 λ = 1.0

$L_v g$ = -0.33 ω_n = 0.69

L_p = -1.30 ζ = 0.36

L_ϕ = -0.71

PILOT A PR = A5 L_δ = 1.44

A control sensitivity below that selected was too sluggish; above, the response was too quick.

The ability to initiate motion in the air taxi around the square was only fair because of the necessity for wing-down into the wind. This complicated the ability to remain within the ground track.

The turn over a spot was complicated because of the necessity to reverse the bank angle going around the turn. Airplane did not appear to be oscillatory and did not tend to be upset by gusts.

Crosswind turns were satisfactory and smooth. Took time for the airplane to get up velocity for a quick stop.

PILOT C PR = A6 L_δ = 0.67

Control sensitivity was set to a level where control movements were small but the response was not jerky.

There was no trouble initiating motion or establishing a rate of movement in the air taxi. Did have trouble stopping precisely at the corners of the square and coming to a hover. Once established, the hover was easy to maintain. Flying with the wing down made it rather difficult to stay close to the ground-track limits.

The turn over a spot was difficult due to attitude changes required and a tendency to overcontrol. Crosswind turns worked out well. It took too much time to stabilize in a hover after the turns. Once established, it was easy to maintain position over the spot. Control activity was moderate. There was overcontrolling laterally and longitudinally. Vertical landings would be marginal due to the bank angle.

CASE 227 (Continued)

Stopped quickly in the quick-stop maneuver with some overcontrolling. No PIO tendency, however. Stick force might prevent overcontrolling.

Longitudinal and height dynamics did not affect the evaluation.

CASE 228

Y_v	$= -0.2$	λ	$= 1.0$
$L_v\, g$	$= -0.33$	ω_n	$= 0.61$
L_p	$= -0.80$	ζ	$= 0$
L_ϕ	$= -0.21$		

PILOT A   PR = U7 $L_\delta = 1.09$

Control sensitivity lower than that selected resulted in the response being too far behind the input in phase and requiring too much stick motion to move the wing. For the sensitivity selected the response was very oscillatory laterally.

Had to have quite a bit of wing-down in order to hold position in the air taxi on the square. So much wing-down is required that it is possible to go into the simulator stops and lose control.

In the turn over a spot there was a tendency to oscillate. There was obviously not enough damping in the lateral mode. Lost control during the turn because of too much oscillation.

Precision hover required holding the wing down too far. Quick stop also required too much wing-down. In order to begin motion into the wind so much wing-down was required that there was a tendency to either hit the simulator stops or to begin to oscillate.

PILOT B   PR = U7 $L_\delta = 0.75$

A poor configuration due to an almost constant lateral oscillation.

Could initiate motion on the square moderately well but bank angle was rather large and there was trouble killing lateral drift. Suspect that Y_V was fairly high. Stabilization of motion was fair. Could stop fairly well at the corners but establishing hover was not easy. Did not do well on the ground track. The weight of the control stick may have caused some of the oscillation. Able to hold heading fairly well in hover but seemed to have difficulty when moving. This may have been an illusion created by the bank angle.

CASE 228 (Continued)

The turn over a spot was fairly hard work. The yaw rate was not maintained too well. There was a tendency to stop the yaw rate in order to stop a drift. Rudder control seemed to be adequate.

Was able to end up close to the hover point in the crosswind turns. Generally, had more trouble longitudinally than laterally in establishing a hover. Lateral oscillations were always present. Precision of hover was fairly good but required pretty hard work. Hover was certainly good enough for a landing.

Strong tendency to overcontrol in the quick-stop maneuver. Did not hold ground track very well and had a problem establishing a hover. Quite a bit of control activity.

Height control was also a problem. Longitudinal dynamics gave trouble especially hovering into the wind.

CASE 229

Y_v	= -0.2	λ =	1.5
$L_v\, g$	= -0.33	ω_n =	0.58
L_p	= -1.90	ζ =	0.52
L_ϕ	= -0.85		

PILOT A PR = A5 L_δ = 2.00

Airplane was extremely well-damped in roll. Required an objectional amount of wing-down into the wind. Performance in both the air taxi around the square and the turn over a spot suffered because of this. Airplane seemed to move from side to side due to gusts. Precision hover was difficult because of the bank angle and the tendency to wallow from side to side. This may have been due to not having the correct bank angle for trim or due to the gusts. The gusts did not seem to roll the airplane.

The quick stops required a lot of wing-down to move sideways into the wind and a lot of wing-up to stop when moving downwind.

PILOT C PR = A5 L_δ = 0.59

Airplane was not too difficult to fly although it took a great deal of effort to fly within the prescribed limits.

In the air taxi around the square, motion was started easily. Was able to hold a preselected rate of movement although the attitude was somewhat uncomfortable. There was some difficulty in stopping precisely at the corners because of large pitch and roll changes required. Stayed fairly close to the ground track although the constant pull on the stick sideways tended to have the heading get off.

Lost control on the turn over a spot due the large inputs required for attitude change coupled with overcontrolling.

The crosswind turns worked out well though it took time to come to a hover after the turn. Control activity was moderate to heavy and control power was adequate. Once established a precision hover was not too difficult to maintain. A vertical landing would be very difficult in the crosswind.

CASE 229 (Continued)

The quick-stop maneuver required excessive attitude changes in roll to initiate motion and to come to a stop, though the stop was fast.

Height control was not difficult and did not affect the maneuvers. Longitudinal dynamics did not affect the evaluation nor did height dynamics.

CASE 230

$Y_v = -0.2$ $\lambda = 1.5$

$L_v\, g = -0.33$ $\omega_n = 0.52$

$L_p = -1.60$ $\zeta = 0.29$

$L_\phi = -0.40$

PILOT A PR = A4-1/2 $L_\delta = 2.00$

Airplane did not oscillate in roll. The air taxi around the square was reasonably good. Airplane had a tendency to slide, which was difficult to recognize, and stop before it would move five or ten feet.

The turn over a spot was reasonably good. Did not stop as quickly as desired in the quick-stop maneuver. Again, the airplane tended to slide too much.

PILOT B PR = A5 $L_\delta = 1.06$

Control sensitivity chosen was perhaps a little too low, but not bad. Had a tendency to overcontrol. Airplane was apparently quite responsive to lateral gusts.

The air taxi around the square was difficult because of lateral drift. Hover was fair, but required effort.

Quite a bit of control activity in the turn over a spot. Hover was fair, but it required work. Maintained the spot fairly well. Attitude seemed more troublesome with a crosswind from the left than from the right.

Crosswind turns were not too bad. Some undershoot and drift problems. Hover was fair and adequate for a vertical landing.

Had a good rate for the quick stop. Some overshooting and undershooting tendency. Pretty good hover.

Bank angle to offset drift was detracting. Hover lacked precision.

CASE 231

Y_v	=	-0.2	λ	=	1.5
$L_v g$	=	-0.33	ω_n	=	0.46
L_p	=	-1.30	ζ	=	0
L_ϕ	=	0			

PILOT B   PR = U7 L_δ = 0.77

In the air taxi around the square there was difficulty with lateral position and the hover at the corners. Stabilizing of velocities was only fair. Tracing out the square was rather poor. Large attitude changes in roll were required. Ability to hold heading was a problem because of the difficulty laterally.

Had trouble remaining over the spot in the turn over a spot, especially laterally. Heading hold was fair to poor.

The crosswind turns were poor. Had difficulty both with altitude and lateral displacement. Hit the simulator stops making large bank angle inputs. Precision of hover was poor. A vertical landing would be doubtful. Control activity was heavy throughout.

Quick stop was not bad considering the large bank angle required. Could hold heading but lateral drift was difficult to stop.

Height control was poor. Longitudinal dynamics were not a very strong factor because the lateral dynamics were so bad.

PILOT C   PR = U8 L_δ = 0.36

Control sensitivity was set fairly low. At a higher setting the response was very jerky. Airplane was difficult to fly and required a great deal of pilot attention just to control the vehicle without putting much attention on flying a precise task.

In the air taxi around the square, the steep bank required to compensate for wind made it rather difficult to initiate motion and hold a preselected rate of movement. Did not stay very close to the ground track or stop precisely at any of the corners.

Had a great deal of difficulty remaining over the spot in the turn over a spot due to large attitude changes in both pitch and roll going around the turn.

Had considerable difficulty establishing over the spot after completing the crosswind turns. Undershot the heading. Control activity was high in the lateral axis and this tended to cause overcontrolling in the longitudinal axis also. Precision hover required large control inputs to correct for gusts. This was a very minimum satisfactory airplane in which to perform a vertical landing.

CASE 231 (Continued)

Overshot several times in the quick-stop maneuver and hit the simulator stops. Control motions were very high for this maneuver.

The large attitude changes caused some difficulty controlling height within limits. Longitudinal and height dynamics did not affect the evaluation of the lateral dynamics.

There was a definite tendency to PIO the vehicle.

CASE 232

	$Y_v = -0.2$	$\lambda = 2.5$
	$L_v g = -0.33$	$\omega_n = 0.47$
	$L_p = -2.90$	$\zeta = 0.64$
	$L_\phi = -1.14$	
PILOT B	PR = U7	$L_\delta = 0.76$

The pilot workload for this configuration is excessive.

Could initiate forward motion for the air taxi fairly well but there was a tendency to change heading when doing this. Had difficulty stabilizing rate of motion going backwards. Also difficulty maintaining the spot in a hover. Rudder control felt sluggish.

The workload in the turn over a spot was fairly high. Required almost continuous lateral and longitudinal corrections. Difficult to stabilize a yaw rate because of the attention required to kill drift.

The crosswind turns were surprisingly good, probably because they were more rapid maneuvers. Was not able to establish a precision hover at any time. Marginally acceptable for a landing. Control activity was excessive.

The quick-stop performance was reasonable. Holding heading was fair.

Height control was fair. The longitudinal dynamics probably did affect the evaluation.

PILOT C PR = U7 $L_\delta = 0.76$

Airplane took a great deal of pilot effort and was difficult to fly. Control sensitivity was increased so that the response would be adequate to compensate for winds but it made the response abrupt and unpleasant.

Overcontrolling in the lateral axis made it rather difficult to maintain the ground track although there was no difficulty initiating motion or holding the prescribed rate of movement. Had trouble stopping precisely and hovering over the corners.

The turn over a spot was very difficult. Got completely out of the forty-foot radius circle due to overcontrolling in the lateral axis.

The crosswind turn was no problem to perform although it took an excessive amount of time to come to a hover over the spot after completion of the turn. Control activity was high. Control power was set high but it made the vehicle uncomfortable to fly. It was difficult to concentrate on the task because of the jerkiness. The precision hover would be adequate for a vertical landing.

CASE 232 (Continued)

Did not stop as quickly as desired in the quick stop. Tended to over-control and overshoot. Height control did not make the maneuver more difficult.

CASE 233

	Y_v = -0.2		λ = 2.5	
	$L_v g$ = -0.33		ω_n = 0.40	
	L_p = -2.60		ζ = 0.38	
	L_ϕ = -0.39			
PILOT A	PR = A4		L_δ = 1.63	

Control sensitivity selection did not seem to be too critical for this configuration.

Had good control of the airplane during the air taxi around the square. Lost sight of the line during the backward flight but the overall impression was favorable. The amount of wing-down required into the wind was not particularly bothersome.

Holding the turn roughly over the spot did not require very hard work for a turn over a spot. Attitude changes were not too objectionable. The crosswind turn seemed smooth, although there was a slight tendency to oscillate rolling out of the turn. The airplane seemed to be well damped so the oscillation may have been due to having the control sensitivity a little too high.

Could not get enough speed up to properly evaluate a quick stop. When the wing was rolled up there was a slight tendency to oscillate again.

PILOT B   PR = U7 L_δ = 1.37

Not a very good configuration. Response was rather abrupt and there was some tendency to oscillate.

Initiating forward motion for the air taxi around the square was not difficult but stabilizing motion was not good. Stopping at the corners and hovering were rather poor. Attitude changes were excessive, particularly bank. Remaining over the ground track was not very good. Not too much mismatch between longitudinal and lateral control. Would like the rudder response a little more sensitive.

Was able to remain over the spot fairly well in the turn over a spot. Hovering was not too good, especially with a crosswind from the left.

The crosswind turns were good and the hovers were fairly good. Hovering into the wind is better than in a crosswind, generally, for the lateral cases that are not too good. Though precision of hover was rather poor, overall it was adequate for a vertical landing. Control activity was too high.

The quick stops were poor due to the attention required for altitude control.

CASE 233 (Continued)

Longitudinal dynamics affected the evaluation and should have been better.

CASE 234

Y_v	=	-0.2	λ	=	2.5
$L_v g$	=	-0.33	ω_n	=	0.36
L_p	=	-2.40	ζ	=	0.19
L_ϕ	=	0			

PILOT A PR = A5 L_δ = 2.00

Airplane has objectionable sideward motion due to gusts, which was difficult to stop. There did not seem to be any moment associated with it. A definite opposite stick movement was required to stop a roll, once started.

In the air taxi around the square, the side movement due to gusts was particularly objectionable and took too long to stop. The turn over a spot also suffered from this translation laterally.

The precision hover wasn't bad. There was no tendency to oscillate but there was a tendency to overshoot bank angle.

Had no particular trouble with the crosswind turns. The airplane was slow to start motion for the quick stops, but once started it moved along fairly well and was easy to stop.

Airplane was generally sluggish.

PILOT B PR = A7 L_δ = 2.00

Control sensitivity selected may have been a little too high resulting in a lot of control application.

Had trouble stopping the airplane where desired in the air taxi around the square. Performance was not very good and fairly hard work was required. Had difficulty stopping but could achieve a hover fairly well. Rudder control could have been better.

In the turn over a spot there was difficulty moving into the wind, obtaining the hover point, and in hovering.

The crosswind turns were fair. Precision of hover was fair to poor. Control activity seemed fairly large. Probably adequate for a vertical landing. By relaxing control a little and allowing some random drift, control activity could be reduced.

In the quick-stop maneuver there was some overshooting and undershooting. Had trouble coming to a hover and altitude control was poor.

Height control was moderately difficult throughout the evaluation. Longitudinal dynamics entered into the evaluation.

CASE 234 (Continued)

Bank angle for wind correction was large. Maneuvers required almost continuous corrections.

CASE 235

Y_v = -0.2 λ = 0.9

$L_v g$ = -0.33 ω_n = 0.62

L_p = -0.30 ζ = -0.29

L_ϕ = 0

PILOT A PR = U7 L_δ = 1.24

With a higher control sensitivity the airplane could get away and go into a PIO. Airplane required wing-down into the wind. It also seemed to oscillate with gusts and had a tendency to roll too fast with pilot inputs.

Had difficulty with the air taxi around the square because of the wing-down attitude combined with the oscillation tendency. Had to be very careful to avoid a PIO.

The turn over a spot was difficult because of the changing wing position going around and because of the lateral response to gusts.

Could not get up enough speed to make the quick-stop maneuver worthwhile. The crosswind turn did not result in a tendency to oscillate because the maneuver ends with the airplane heading into the wind and could be readily handled longitudinally.

PILOT C PR = U9 L_δ = 0.42

Airplane takes considerable pilot effort to keep from losing it laterally by overcontrolling and hitting the simulator stops. Control sensitivity was set low enough to prevent jerky response from a small control input, yet high enough to give adequate control. Airplane seemed as though it would diverge from a lateral input without even overshooting.

Had extreme difficulty in stabilizing and holding a preselected rate of movement in the air taxi around the square. Difficult to stop precisely at the corners. Attitudes were not excessive to move over the ground and compensate for wind. Seemed to stay fairly close to the ground track although the vehicle was by no means under complete control. Rudder sensitivity was low, though adequate. Could hold a preselected heading.

Could not remain over the spot in the turn over a spot. Overcontrolled constantly laterally.

The crosswind turn worked out fairly well although the time to accomplish the turn and come to a hover after completing a turn was excessive. Undershot on the turn. Control activity was high.

Precision hover was adequate for a vertical landing although control activity was moderate.

CASE 235 (Continued)

Could not get a large speed buildup for the quick stop because an excessive bank angle would have been required and control of the vehicle could have been lost.

Height control was difficult because the maneuvers were so difficult. Longitudinal dynamics did not affect the evaluation.

CASE 236

	Y_v	= -0.2		λ	= 3.0
	$L_v g$	= -0.33		ω_n	= 0.33
	L_p	= -3.00		ζ	= 0.24
	L_ϕ	= 0			
PILOT A	PR	= A4		L_δ	= 1.01

Control sensitivity was sufficiently high for control purposes without tendency to oscillate.

Air taxi around the square did not present any problem except going backwards too rapidly and overshooting. Ability to initiate motion into the wind was very good.

Did not get up much speed for the quick stop. Amount of wing-down required into the wind was not bothersome because there was no tendency to oscillate. This was due to good airplane damping or the control sensitivity selected.

The turn over a spot did not require very hard work. The crosswind turn did not present a problem though the airplane backed up after rolling out but this was due to pilot performance, not due to airplane characteristics. Could not pick up much speed for the quick stop.

PILOT B PR = A4 L_δ = 1.30

Control sensitivity was selected a little lower than otherwise desirable in order to avoid an abrupt response.

Performance in the air taxi around the square was fairly good. Stabilizing the rate of motion was not too easy, particularly into the wind. Could stop at the corners and hover reasonably well. Attitude changes required to offset the wind were fairly large.

Could stay over the spot reasonably well in the turn over a spot. Attitude control was more difficult heading downwind.

The crosswind turns worked out well. Precision of hover was reasonably good. Adequate for landing. Control activity was moderately high.

Altitude control was the biggest problem in the quick-stop maneuver. Controlling rate of motion downwind laterally was troublesome. Attitude changes were fairly large making the stop.

CASE 237

Y_v = -0.2 λ = 0.5

$L_v\, g$ = -1.00 ω_n = 1.90

L_p = -1.80 ζ = 0.40

L_ϕ = -3.98

PILOT B PR = A5 L_δ = 0.74

This configuration required too much effort by the pilot to obtain precision. Too much bank angle was required to prevent drift in a crosswind.

Had some difficulty initiating forward motion because of the difficulty in pushing the stick directly forward while holding it off to the side. Once established, the forward velocity could be stabilized reasonably well. There was a little problem coming to a stop because of lateral drift. Performance on the square was not very good, especially coming backwards but this part of the maneuver was not a strong point in the evaluation.

Was not able to make the turn over a spot very well. Could initiate the turn but not maintain a really good constant rate because of the large changes in bank required.

The crosswind turns were not too difficult except for establishing the hover point and coming to a hover. Hover was not solid but adequate for a vertical landing.

Had difficulty in the quick stops maintaining ground track. Had a tendency to turn into the wind. Altitude control was good.

Longitudinal mode enters into the evaluation somewhat. Control activity was fairly high throughout.

PILOT C PR = U9 L_δ = 0.93

Control sensitivity was set high to give enough control in the crosswind. This may have tended to cause PIO.

In the air taxi around the square, it was fairly easy to initiate motion but difficult to maintain it because of lateral inputs. It was difficult to stop precisely and come to a hover at the corners. Attitude changes in roll were excessive. Got into lateral PIO. Rudder control was adequate. Could hold a heading once established.

The turn over a spot was difficult because of large lateral inputs. There was no difficulty in initiating a turn rate but it was very difficult to keep it established and practically impossible to stop on a preselected heading because of lateral inputs.

CASE 237 (Continued)

Undershot in the crosswind turns and had difficulty establishing over a point after the runs. Heading was readily established, but it was very difficult to hold position. Control activity was excessive. A precision hover was very difficult since the gusts caused a tendency to overcontrol laterally.

Hit the simulator stops in the quick stop and practically lost control.

Height control didn't enter into the evaluation because the lateral control took all the attention.

CASE 237 (RERUN)

	Y_v	= -0.2	λ	=	0.5
	$L_v g$	= -1.00	ω_n	=	1.90
	L_p	= -1.80	ζ	=	0.40
	L_ϕ	= -3.98			
PILOT C	PR	= U8	L_δ	=	1.00

Control sensitivity was set high in order to make the stick inputs small enough to be satisfactory. Response was extremely abrupt and the vehicle was very uncomfortable to fly. Had a feeling of instability throughout the flight. Controllability was difficult. Substantial pilot skill and attention was required to retain control particularly during ground tracking.

CASE 238

	$Y_v = -0.2$		$\lambda = 0.5$
	$L_v\, g = -1.00$		$\omega_n = 1.87$
	$L_p = -1.30$		$\zeta = 0.27$
	$L_\phi = -3.73$		
PILOT B	PR = A6		$L_\delta = 0.76$

Had trouble killing lateral drift in the air taxi around the square. Bank angle was fairly high. Hover not too good.

The turn over a spot was fair with some drifting off the spot.

Overcontrolled in pitch during one of the crosswind turns. Hover was fair.

Quick stops were not very good.

PILOT C PR = A3 $L_\delta = 0.56$

The air taxi around the square was performed without any difficulty. It was easy to initiate motion in any direction and to stabilize a preselected rate of movement. Able to stop fairly precisely at the corners. No excessive attitude changes appeared necessary to control the vehicle. Ground track was fair to moderately good. There was some overcontrolling in the pitch axis. Could remain over a spot in hover. Rudder control was adequate.

The crosswind turns were accomplished with very little control activity in the lateral axis and some overcontrolling longitudinally. There was no difficulty establishing a position over the spot after the turns. Control activity was moderate and there was adequate control power.

Stopped quickly in the quick-stop maneuver although speed did not get very high. There were no excessive attitude changes necessary to perform the quick stop. Heading did not vary substantially and altitude caused no problem.

Longitudinal dynamics may have affected the evaluation. There were some rather large and abrupt pitch inputs.

CASE 238 (RERUN)

	Y_v	= -0.2	λ	=	0.5
	$L_v\, g$	= -1.00	ω_n	=	1.87
	L_p	= -1.30	ζ	=	0.27
	L_ϕ	= -3.73			
PILOT C	PR	= A4	L_δ	=	0.60

Airplane was fairly easy to fly but required too much bank to correct for wind. Stick movements were fairly high but not enough to really be objectionable. It was fairly easy to remain within the ground track requirements, to turn over a spot, and to perform precision hover.

CASE 239

Y_v	= -0.2	λ	= 0.5
$L_v g$	= -1.00	ω_n	= 1.84
L_p	= -0.70	ζ	= 0.11
L_ϕ	= -3.43		

PILOT B PR = U9 L_δ = 0.61

Had difficulty both laterally and longitudinally maintaining a hover. Difficult to keep from drifting in the turn over a spot.

Crosswind turns were fairly good. Had trouble longitudinally.

PILOT C PR = U7 L_δ = 0.36

It was possible to perform the air taxi around the square but because of the crosswind more than half of the available control power was taken to hold the vehicle over the ground line which did not leave a great deal of control power for maneuvering. For this reason it was difficult to maintain a constant rate over the ground. The fact that so much control power was used just to correct for wind made it difficult to remain within the ground track and hold the preselected rate.

In the turn over a spot the difficulty again was the crosswind and lack of control power after correcting for wind. Rudder control was adequate.

Tended to lose control a little after the crosswind turn but did not overshoot or undershoot. It was fairly easy to establish heading although it was difficult to hold position over the spot after the turn. Control activity was high but not excessive. Control power was adequate. Precision hover was difficult because of the lateral inputs.

Stopped quickly in the quick-stop maneuver but the ground speed was very slow even with full stick input. Control motions laterally were excessive.

Height control was erratic due to preoccupation with the lateral inputs. Longitudinal and height dynamics did not affect the evaluation again because of preoccupation with lateral control.

Vehicle could get into a PIO easily if not watching for it.

(Pilot does not say why he did not increase the control sensitivity to correct the control power deficiency except to say that "when flying a system like this you kind of tone down your control inputs to a very minimum so that you don't lose control.")

CASE 240

	Y_v	$= -0.2$	λ	$= 1.0$
	$L_v g$	$= -1.00$	ω_n	$= 1.20$
	L_p	$= -2.80$	ζ	$= 0.50$
	L_ϕ	$= -2.25$		
PILOT A	PR	= A3	L_δ	$= 2.00$

Did not have much trouble with the air taxi around the square. Had to hold wing down but not excessively.

The turn over a spot was satisfactory. Nothing particularly disturbing about it. Controlling the airplane in the crosswind turn was quite satisfactory. The time required to accomplish the maneuver was not excessive. Felt that control was good throughout the maneuver. Accomplished the turn smoothly and came to the spot.

Airplane was very stable and felt highly damped. No overshooting.

PILOT B PR = A5 $L_\delta = 1.31$

With a higher control sensitivity there was a tendency to get into a high frequency, small amplitude PIO. Response was somewhat abrupt but not bad.

Initiating motion in the air taxi, holding heading, and staying within ground-track limits were okay. Overall it was a fair performance. The weight of the stick, when holding it to the right, affected the precision of control. Relaying the grip on the stick caused it to start to fall and then tightening up tended to cause a PIO.

The turn over a spot, fair. Hovering into the wind seemed good; downwind and crosswind, fair.

The crosswind turns were fair but there was an appreciable pitch attitude required to offset the wind and a tendency to end up short longitudinally. Precision of hover was reasonable and adequate for landing.

Overall, the quick stops were fair to poor. Tendency to overcontrol and overshoot. Ended in a good hover; however, had height control problems.

CASE 241

Y_v	= -0.2	λ	= 1.0
$L_v g$	= -1.00	ω_n	= 1.15
L_p	= -1.40	ζ	= 0.26
L_ϕ	= -1.65		

PILOT B   PR = U7 L_δ = 0.79

This was not a good configuration, lacking precision of control. A good hover was difficult to establish and the workload was very high.

Could establish a reasonably stabilized velocity in the air taxi around the square but the ability to stop at the corners was not very good. Could not really establish a good hover. Ground tracking was poor because of large attitude changes in both pitch and roll. Not able to relax the grip on the stick because of its weight while holding it to the side.

The turn over a spot was poor. Could not establish a good hover. Difficult to maintain a steady-state yaw rate. Had some trouble with headings, also.

The crosswind turns were bad. Either gained or lost altitude in the turns. Hover was barely adequate for a vertical landing. Lateral and longitudinal drift was excessive.

Quick stop was fair but, again, hover was poor. Drifted some from the spot. Height control was fair to poor. Control activity was quite high especially in the hover. Longitudinal amplitude changes were fairly high.

PILOT C   PR = U7 L_δ = 0.56

Control had a sluggish feel with the sensitivity down so it was increased to give a more crisp feel which was better for exact maneuvering. Airplane had a definite tendency toward overcontrolling and PIO.

It was easy to initiate movement in the air taxi around the square but rather difficult to keep it going due to distraction caused by the lateral stick movements. Had some difficulty stopping at the corners. This again was due to the lateral movements of the stick. Attitude changes in roll were excessive. Had difficulty remaining within the ground track.

In the turn over a spot, there was some difficulty remaining over the spot. Hover was possible but it took most of the pilot's attention. Rudder control was adequate. Had no tendency to overshoot or undershoot rolling out on a preselected heading.

CASE 241 (Continued)

The crosswind turns worked out very well considering the vehicle's characteristics. Overshot on the roll inputs but readily established position over the spot and heading. Control power seemed a little low. Precision hover was somewhat difficult but adequate for a vertical landing.

Stopped quickly in the quick-stop maneuver but the attitude change was rather great and there was a tendency to overcontrol. Could not give much attention to height control so it got off somewhat.

Longitudinal and height dynamics did not affect the evaluation.

CASE 242

	$Y_v = -0.2$		$\lambda = 1.0$
	$L_v g = -1.00$		$\omega_n = 1.12$
	$L_p = -1.00$		$\zeta = 0.09$
	$L_\phi = -1.25$		
PILOT A	PR = U7		$L_\delta = 1.04$

In the air taxi around the square, considerable wing-down into the wind was required to hold track over the ground. The airplane seemed very close to being dynamically unstable. As a result, it was difficult to maintain a precise pattern over the ground because of the changing wing angle which caused drift sideways. The airplane was too responsive to gusts and roll was much too high. Had a great deal of trouble downwind in stopping at the corner. Had to roll considerably to stop the velocity and had difficulty because of oscillation due to gusts. Rudder control was satisfactory.

The turn over a spot was extremely bad due to difficulty coordinating longitudinal and lateral changes going around the turn.

The crosswind turn was satisfactory in that there was adequate rudder and roll control and coordination was satisfactory.

Could not make a good quick stop because of difficulty maintaining a good velocity. A large bank angle was required and the gusts caused trouble raising and lowering the wings.

PILOT C PR = U8 $L_\delta = 0.55$

Vehicle was practically uncontrollable with a lower value of sensitivity. There was a definite possibility of pilot-induced oscillation and loss of control with this vehicle.

In the air taxi around the square there was difficulty in stopping precisely and coming to a hover at the corners. Had difficulty in remaining within the ground track. Overcontrolled constantly on the lateral axis.

In the turn over a spot there was great difficulty remaining over or near the spot. The tendency to overcontrol in roll was the prime reason for the poor performance.

The crosswind turns worked out well. There were no overshoot or undershoot tendencies and no difficulty in establishing heading after rollout. Hover took time to develop and was erratic due to overcontrol in the lateral axis. Lateral control activity was excessive. The bank angle in precision hover was too steep to be comfortable and to perform a vertical landing.

CASE 243 (Continued)

Y_v appeared to be high and quite a bit of bank angle was required to offset the wind.

CASE 244

$$Y_v = -0.2 \qquad \lambda = 1.5$$

$$L_v g = -1.00 \qquad \omega_n = 0.90$$

$$L_p = -1.70 \qquad \zeta = 0.22$$

$$L_\phi = -1.07$$

PILOT A PR = A5 $L_\delta = 2.00$

Control sensitivity could be set high because the airplane had no tendency to oscillate. Sensitivity may have been slightly high but it was satisfactory.

In the air taxi around the square about 8 degrees wing-down into the wind was required to hold position. Initiating motion into the wind was difficult because 2 to 4 degrees more wing-down was required which was unpleasant. It was also difficult to come to a stop and stabilize because of the wing-down reference attitude. Moving laterally downwind there was a tendency to overshoot because of the excessive attitude required to stop the airplane.

The turn over a spot was very difficult because of an inability to coordinate precisely the longitudinal and lateral nose positions in order to remain over the spot.

The quick-stop maneuver was unpleasant because of the necessity for about 15 degrees wing-down to get up a good velocity. There was a tendency to be not too precise in stopping because of the wing-down zero position rather than a wings-level position.

The crosswind turn was satisfactory because the airplane did not have a tendency to oscillate or overshoot laterally. A slightly oscillatory airplane that did not require a wing-down reference would be more acceptable than one with very good roll tendencies, such as this one, that did.

Effect of the wing-down deficiency is not easily compensated for by the pilot.

PILOT C PR = A5-1/2 $L_\delta = 0.58$

In the air taxi around the square, initiating motion into the wind was troublesome because of the steep bank angle required. It was fairly easy to initiate and maintain a preselected rate of movement in the other directions. There was some difficulty in stopping precisely over the corners due to the steep bank angle and to flying with the stick far off center. Maintaining an accurate ground track was difficult because of the bank angle.

In the turn over a spot it was difficult to maintain position due to the rapid attitude changes which were necessary in order to compensate for crosswinds.

CASE 243

Y_v	=	-0.2	λ	=	1.5
$L_v\,g$	=	-1.00	ω_n	=	0 ′4
L_p	=	-2.10	ζ	=	0.43
L_{ϕ}	=	-1.67			

PILOT A PR = A5 L_{δ} = 1.77

Airplane had a tendency to slide laterally and therefore was hard to control moving straight ahead with a crosswind. Control power was adequate. Bank angle to counter the crosswind did not feel excessive.

The main difficulty with the turn over a spot was again the sliding tendency when the airplane was disturbed. It seemed difficult to bring it back over the spot.

Had no real problem in executing the crosswind turn. The maneuver seemed satisfactory though there was a slight tendency to oscillate in roll.

Would like to have stopped a little quicker in the quick-stop maneuver for the amount of roll control applied. No adverse comments otherwise.

PILOT B PR = A6 L_{δ} = 1.14

Control sensitivity could not be set higher because of an abruptness in response and because it was too easy to hit the simulator stops.

In the air taxi around the square there was a little difficulty stabilizing motion and also stopping and coming to a hover at the corners. Ability to stay within the ground track was only fair. Rudder response was not as quick or as sensitive as desired. Ability to hold heading was fair to good.

The turn over a spot required a considerable amount of pilot effort but reasonable limits could be maintained. Precision of hover was fair to poor. Fairly large attitude changes were required all the way around. Could initiate a turn reasonably well but was not able to stabilize the turn because of drift problems. Stopped on a preselected heading fairly close most of the time.

The crosswind turns were not bad but there was a problem establishing a hover. Precision of hover was fair to poor. A vertical landing could be made but it would take considerable effort, control activity, and time.

The quick stops were not bad to the left but poor to the right. Altitude control and the precision of stop and hover were not very good.

The longitudinal dynamics did enter into the evaluation to some extent.

CASE 242 (Continued)

Excessive attitude changes developed during the quick stop. Control motions were excessive. Developed a PIO maneuver which could have resulted in the loss of the aircraft in the real case.

Longitudinal and height dynamics did not affect the evaluation of lateral dynamics. Overall, the bank angle to correct for wind was excessive. There was an objectionable unstable feeling in the lateral axis.

CASE 245

Y_v	$= -0.2$	λ	$= 1.5$
$L_v g$	$= -1.00$	ω_n	$= 0.87$
L_p	$= -1.40$	ζ	$= 0.06$
L_ϕ	$= -0.62$		

PILOT A PR = A4 $L_\delta = 1.20$

Did nc˙ have too much difficulty with the air taxi around the square, although the ability to initiate motion into the wind was unsatisfactory. About 9 or 10 degrees wing-down was required to hold position in the wind. Once this was established a preselected rate of movement could be stabilized.

The turn over a spot lacked precision because of difficulty when ιurning toward the 180-degree point. Did not reverse wing position properly from right wing-down to left wing-down coming around this point.

The quick-stop maneuver was not as good or as fast as desired because of difficulty getting up speed laterally.

There was no particular problem with the crosswind turn which was satisfactory to get ready to hover over a spot to land.

PILOT B PR = A6 $L_\delta = 1.19$

Control sensitivity was selected to be able to hold and maintain a rather large bank angle and make appreciable bank angle corrections. Airplane seemed to have high Y_v and poor roll damping. There was a continuous lateral oscillation which was a function of the control sensitivity and the lateral dynamics. Generally, a poor configuration.

Was able to initiate motion in the air taxi around the square but stabilizing the rate was not too good. Ability to stop precisely also was not good and hovers were only fair, in that they took quite a bit of pilot effort. Fairly large pitch attitude changes were required in addition to fairly substantial bank angle changes. Was not able to stay over the ground track especially well. Ability to remain within the ground track very often is just an indication of the pilot effort required to do so. It is more a visibility problem and a matter of pilot effort than a control problem, at least for the configurations that are rated in the acceptable, unsatisfactory region and below. Hence, pilot performance may not be indicative of the configuration. Lateral control felt rather tight because of the continuous pilot-induced oscillation; longitudinal control, a bit loose.

Was able to do the turn over a spot reasonably well. Had difficulty coming to a hover, however, and in making small drift corrections. There certainly is a correlation between performance and the gusts.

CASE 244 (Continued)

The crosswind turns worked out well. There was no excessive time used, no undershoot or overshoot tendencies, control activity was low, and control power adequate. Once in a precision hover it was easy to maintain although the angle of bank would make a vertical landing difficult to perform.

The quick stop worked out well. There were no excessive attitude changes during the stop itself although very steep banking was required to initiate and maintain the translational motion.

Height control requirements did not make the maneuvers more difficult. Longitudinal and height dynamics did not seem to affect the evaluation.

Airplane felt well-damped and a little sluggish.

CASE 245 (Continued)

Ended up reasonably close to the spot following the crosswind turns, but did not establish a very good hover. Had considerable trouble longitudinally but it was easier to hover into the wind than it was crosswind. Still had a tendency to keep a small-amplitude lateral oscillation going. By working hard, an adequate hover for vertical landing could be obtained. Control activity was substantial.

The quick stops were pretty bad. Had trouble holding lateral velocity and also tracking. Hover was not good. There was some trouble with height control but generally height was within limits.

Lateral oscillation could be reduced somewhat by a reduction in pilot gain.

CASE 246

$Y_v = -0.2$ $L_\phi = -0.93$

$L_p = -2.70$ $\omega_n = 0.69$

$\lambda = 2.5$ $\zeta = 0.29$

$L_v g = -1.00$

PILOT B PR = A6 $L_\delta = 1.38$

Pilot comments missing.

PILOT C PR = U7 $L_\delta = 0.49$

A higher control sensitivity would have made the response very jerky and abrupt.

There were no problems initiating movement or holding a rate of movement in the air taxi around the square. There was some trouble stopping precisely at the corners. It took quite a bit of time to come to a hover because of the off-balance feeling of the lateral control. Did not seem to be able to stay within the ground track-limits. No difficulty with rudder-control response or holding heading. The bank angle required to correct for the ten-knot wind was excessive.

Was unable to perform the turn over a spot within the 40-foot circle. Roll attitude was excessive during the turn.

After completing the crosswind turn there was little difficulty establishing heading but there was difficulty establishing position. It took a great deal of time to come to a hover. Control activity was moderate to high for precision hover. The smallest gusts necessitated excessive control movements for correction.

The vehicle stopped quickly in the quick-stop maneuver but there was an excessive attitude change and overshooting. Control motions were moderate to high.

The lateral maneuvers required so much attention that it was difficult to maintain height control within the prescribed limits.

CASE 247

$Y_v = -0.2$ $L_\phi = -1.68$

$L_p = -3.00$ $\omega_n = 0.73$

$\lambda = 2.5$ $\zeta = 0.48$

$L_v g = -1.00$

PILOT A PR = A4-1/2 $L_\delta = 1.34$

Airplane was easily handled in lateral control. It was well damped. Longitudinal control was not as good as lateral.

In the air taxi around the square too much wing-down into the wind was required. Had trouble holding the nose straight. There seemed to be a tendency to yaw.

The turn over a spot was not too bad but it had to be well coordinated to remain over the spot. As a result there was a tendency to drift. The airplane seemed to be well damped in roll so that any oscillation would be because the lateral control sensitivity was set too high and would be pilot induced.

Following the crosswind turn there was a tendency to drift downwind because the nose was not dropped far enough to hold over the spot. This was due to the longitudinal response which was not as desirable as the lateral.

PILOT B PR = A6 $L_\delta = 1.17$

The control sensitivity was set so as not to overcontrol and to keep the response from being too abrupt. A fairly high value was selected, however.

In the air taxi, the ability to initiate motion was not too bad. Stabilization of motion was fair. Could stop with fair precision. Hover was pretty good but took a fair amount of time to establish. Precision of ground track around the square was fair to poor. Would prefer a combination of position and force-feel control rather than position control alone. Rudder could be more sensitive, but could hold heading fairly well.

The turn over a spot lacked accuracy in remaining over the spot but wasn't really very bad. A fair amount of attitude control deviations were required both laterally and longitudinally. Almost always it seems that more bank angle is required to kill the drift when hovering with the wind from the left than with the crosswind from the right.

The crosswind turns were fair and the hovers fairly good. Hover was good enough for a vertical landing but it does take time and effort. Control activity was moderately high.

CASE 247 (Continued)

The quick stop to the left was pretty good. Some overshooting but not bothersome. The one to the right could not really be considered a quick stop at all. A lot of altitude was lost and not much ground speed was attained.

There was a fair amount of difficulty maintaining height. Longitudinal dynamics definitely affected the rating. Overall, the bank angles required to offset wind conditions were too large and there was a general lack of precision of control.

CASE 248

Y_v	=	-0.2	L_ϕ	=	0
L_p	=	-2.30	ω_n	=	0.63
λ	=	2.5	ζ	=	0
$L_v g$	=	-1.00			

PILOT A PR = A5-1/2 L_δ = 1.77

Control sensitivity may have been a little too high. Airplane was fairly well damped in roll but it required an objectional amount of wing-down into the wind.

Performance in the air taxi around the square was adequate. Must be very careful about wing position in the turn over a spot. If the wind direction were not known it would be a problem to keep from sliding.

Could not do a quick stop because of the lack of ability to get up speed without banking an objectional amount. There was no tendency to lose control in the crosswind turn.

PILOT C PR = U7 L_δ = 0.61

Airplane was difficult to fly because of the steep bank angles required, a tendency to overcontrol, and the feeling that it was not too well-damped.

The air taxi around the square was difficult because of the excessive attitude changes. Had difficulty stopping precisely at the corners and coming to hovers. Stayed fairly close to the ground track except at the corners when changing from translation to steady hover. The turn over a spot was difficult because of the attitude changes required during the turn.

The crosswind turns worked out well. No excessive time was used after completing the turn, there were no overshoot or undershoot tendencies and there was no difficulty establishing heading or coming to a hover over the spot. The bank angle in the hover was such that the airplane would be very poor for a vertical landing.

Could not get up much velocity for the quick stop even with large bank angles.

Control motions required throughout the flight were moderate to heavy and most of this was overcontrolling laterally. Height control requirements did not make the maneuvers more difficult. Longitudinal or height dynamics did not affect the evaluation.

[The dynamic check runs made immediately prior to each of the above evaluations were examined and found to be identical and neutrally stable.]

CASE 249

Y_v	= -0.2	L_ϕ	= 1.97
L_p	= -6.30	ω_n	= 0.48
λ	= 6.0	ζ	= 0.52
$L_v g$	= -1.00		

PILOT A PR = A2-1/2 L_δ = 2.00

Airplane was very highly damped. Had an inability to translate laterally quickly. There was no concern about losing control regardless of how violently the controls were applied.

In the air taxi around the square it seemed to take a little while for the airplane to get moving laterally along the last segment into the wind.

The turn over a spot was reasonably good, but required too much effort. Had to roll the wings to the opposite side coming through the 180° position although the magnitude of the attitude change did not seem objectionably large. Precision hover could be a good maneuver with a little effort except that it seemed to take too long for the airplane to be moved back over the spot when it was moved off laterally.

The crosswind turn could be flown as fast as desired without concern about losing the vehicle. It did not have the preciseness of control that was desired, however, because of the same lateral slowness - like the airplane had a great amount of inertia.

PILOT B PR = A5 L_δ = 2.00

Had to work a little too hard to perform the maneuvers with the desired precision. Many times it was not really possible to get close precision accuracy. Generally, though, this was a fair configuration. Could use a high control sensitivity without too much abruptness of response. The configuration probably had a large Y_v. It required fairly large bank angles and it was very easy with high sensitivity to hit the simulator stops and overcontrol. This was especially true in the quick stops.

In the air taxi around the square, motion could be initiated fairly easily, stabilization was fair, and the ability to stop was fairly good. There was some difficulty obtaining the hover point.

There was some difficulty trying to maintain position within reasonable limits in the turn over a spot. Could initiate a turn okay but possibly did not stabilize too well on turn rates. Position-hold over the spot was rather loose. Could stop on a heading fairly well.

The crosswind turns were fairly good and precision of hover was fair. Control activity in hover was rather high but the hover was adequate for a vertical landing.

CASE 249 (Continued)

The quick stops were fair with some tendency to overshoot. The hover at the end of the maneuver was fairly difficult.

The longitudinal dynamics gave some difficulty and introduced some effect on the rating. There was no oscillatory tendency laterally.

CASE 250

Y_v	=	-0.2	L_ϕ	=	-0.77
L_p	=	-6.10	ω_n	=	0.44
λ	=	6.0	ζ	=	0.33
$L_v g$	=	-1.00			

PILOT A   PR = A4 L_δ = 2.00

Could use high control sensitivity because the airplane seemed to be well-damped in roll.

Required an excessive attitude change in roll to initiate an action into the wind and to hold hover position. Rudder control was satisfactory.

In the turn over a spot there was a coordination problem because of both longitudinal and lateral attitude changes.

Because the airplane was so well damped and so precise in roll, the quick stop maneuver felt comfortable even with 15 degrees or more roll attitude. There was very little difficulty with this much roll. There was no problem with the crosswind turn once rudder was coordinated with roll angle.

There were some longitudinal pitch problems because of the pitch change with wind. There was no problem with oscillation or with overshooting.

PILOT C   PR = A5 L_δ = 0.85

With the control sensitivity selected, the response was smooth and not jerky. There was no tendency for pilot-induced oscillation. Vehicle was easy to fly and felt very stable.

In the air taxi around the square it was easy to initiate and maintain movement, and fairly easy to stop precisely at the corners although this was hampered by the steep bank angle required to correct for the wind. Stayed fairly close to the ground track although there was some wandering. This seemed to be due to the slow response of the vehicle as though the response was lagging the input.

The turn over a spot was easy to perform although the steep bank angles caused some drifting from the spot. There did not seem to be any tendency to overcontrol but the steepness of the angles made it difficult to change bank in order to compensate for the wind.

The crosswind turns worked out well without using an excessive amount of time to accomplish the maneuver. There were no overshoot or undershoot tendencies, control activity was light, and there was very adequate control power. Precision hover was easy to maintain, although the amount of bank would cause difficulty in a vertical landing.

CASE 250 (Continued)

The quick stop maneuver was performed quickly and no excessive attitude changes were required. There was no difficulty holding heading or altitude and control motions were light.

Longitudinal and height dynamics did not affect the evaluation of the lateral dynamics.

CASE 251

Y_v	= -0.2	L_ϕ	= 0
L_p	= -6.00	ω_n	= 0.41
λ	= 6.0	ζ	= 0.19
$L_v g$	= -1.00		

PILOT A PR = A3 L_δ = 1.73

There was no oscillation tendency even with high control sensitivity.

The airplane was fairly easy to handle although it seemed to take a rather long time to initiate a lateral correction into the wind. A high wing-down attitude was required but control seemed positive. Tracking performance around the square was not as good as it should have been because the start was inadvertently 15 feet low and an altitude correction had to then be made.

Had trouble with the turn over a spot because of the very large wing-down angle to remain over the spot particularly through the 180° point. The turn was performed sort of continuously and at this point the bank angle had to be shifted from one direction to the other. There was good positive control and no worry about oscillation.

Had such good control in the crosswind turn that there was no fear in moving the airplane rapidly. In lining up to start the run it appeared to take quite a bit of time to move the airplane laterally, particularly into the wind.

The quick stop required considerable wing-down into the wind which is a bad feature, but there was no apprehension about getting it down as required.

PILOT B PR = A5 L_δ = 1.69

In the air taxi it was not too difficult to initiate motion but there were problems staying on the ground track. Coming to a stop and hovering at the corners was fair but moderately high pilot effort was required. There were excessive attitude requirements laterally and occasionally the longitudinal attitudes were bothersome, also.

Control felt a bit tight laterally because of abruptness of response. It felt a little loose longitudinally so there was a mismatch. Rudder could be more sensitive.

The turn over a spot was not too good because of the tendency to make wrong corrections to attitude.

The crosswind turns turned out fairly well. It took time to establish a hover, however. There was a tendency to drift after making the turn and stop, and control activity was moderately high. Precision hover was adequate for a vertical landing but it required work. It was sometimes difficult to move the airplane laterally into the wind.

CASE 251 (Continued)

The quick stops were rather poor and there was difficulty hovering perhaps because the visual references were not as good over this part of the display as when over the square. There was some overshooting and altitude control was a problem.

Longitudinal dynamics did at times affect the evaluation. Overall, the precision of control was sufficient to do the tasks reasonably well.

CASE 252

Y_v	= -0.2	L_ϕ	= 0
L_p	= -3.00	ω_n	= 0.57
λ	= 3.1	ζ	= 0.07
L_{v_g}	= -1.00		

PILOT B PR = A5 L_δ = 0.89

It was quite difficult to initiate motion laterally into the wind in the air taxi around the square. Bank angles were high. Could stabilize motion fairly well both longitudinally and laterally although there was a tendency to overshoot velocity. The hovers were sometimes good, sometimes not so good. Ability to remain within the ground track was rather poor.

The turn over a spot was only fair. Ability to initiate a turn was okay but there was some difficulty in holding the desired turn rate. The turn rate seemed to suffer because of the changes in the pitch and roll attitude during the turn. Was able to stop at a preselected heading fairly well.

The crosswind turns resulted in pretty fair performance. Acquiring the hover point was a problem and coming to a complete hover took too much time. Hover was adequate for a vertical landing, however. Control activity was moderate to heavy.

Could stop as quickly as desired in the quick-stop maneuver and the attitude changes were not too great. Was able to hold heading. Control motions were moderate. Altitude control was fair.

Longitudinal and height dynamics did not affect the evaluation.

PILOT C PR = A5 L_δ = 0.64

Vehicle would have been rather difficult to control with less sensitivity because of low frequency or low damping.

In the air taxi around the square it was easy to initiate motion but hard to hold the preselected rate due to the inputs in the lateral axis. Attitude changes were excessive. A great deal of pilot effort was required to remain close to the desired ground track limits. Rudder and pitch controls did not enter into the evaluation.

It was difficult to turn over a spot because of the rather large attitude changes necessary to compensate for wind and gusts. There was no problem initiating a turn but it was rather difficult to hold the preselected turn rate because of the large lateral inputs.

The crosswind turns worked out well. There was no problem in establishing a heading although it was difficult to remain in a desired spot over the ground. Control activity was high and control power a little low. Precision

hover was difficult to establish and maintain because of the attitude changes necessary. It would be minimally satisfactory to perform a vertical landing.

In the quick-stop maneuver the vehicle stopped as quickly as desired although an excessive attitude change was required. Overshooting of the spot occurred, requiring the use of full lateral control. Control motions were higher than desirable. Height control was difficult because of the large lateral inputs.

CASE 253

$Y_v = -0.2$ | $\lambda = 1.5$

$L_v g = -1.00$ | $\omega_n = 0.82$

$L_p = -1.00$ | $\zeta = -0.18$

$L_\phi = 0$

PILOT A PR = A6 $L_\delta = 2.00$

Had to hold too much wing-down into the wind. It was very difficult moving straight forward with a wing down.

The turn over a spot was not too difficult but required a great deal of wing-down into the wind. Precision hover was adequate.

Ability to establish position over a spot following the crosswind turn was not good. To get the desired amount of wing-down required getting close to the simulator stops. Stopped quickly following the turn.

There was a tendency to overcontrol in roll.

PILOT B PR = A5 $L_\delta = 1.35$

The control sensitivity was selected on the basis of a PIO tendency. Even with the compromise value selected, there was some tendency toward PIO.

The air taxi around the square was not too bad and the hover was fair. Overall ability to stay within limits was fair. There seemed to be some rather large attitude changes in bank required. Rudder control could be a little more sensitive, more responsive.

The turn over a spot was fair, although there was some tendency to not get the proper altitudes initially at each of the four points. Was able to initiate a turn, stabilize, and stop on a heading fairly well.

The crosswind turns were fairly good, although it took a little too long to come to a hover. Had some undershoot tendencies and tended to drift aft. Precision of hover was generally fair. Adequate for a vertical landing. Control activity was substantial but not excessive. There was some tendency to oscillate laterally.

The quick stops weren't too bad. Could come to a fairly good hover, and altitude control wasn't too bad.

Longitudinal control took more manipulation than the lateral.

CASE 254

Y_v = -0.2		λ = 1.2	
$L_v g$ = -1.00		ω_n = 0.93	
L_p = -0.30		ζ = -0.37	
L_ϕ = 0			

PILOT A PR = U7 $L_{\dot{\delta}}$ = 1.73

Had to hold the wing down too far into the wind. Airplane felt unstable laterally or very close to being unstable.

Did not like the ability to initiate motion into the wind because of the necessity to hold wing down too far. It affected the performance around the square pattern. There was a tendency to overcontrol or undercontrol depending on whether motion was with or against the wind.

Had great difficulty with the turn over a spot. Lost control because of an inability to fly correctly with the wing over so far. A vertical landing would be very difficult because of the wing-low attitude. Leveling the wings near the ground for landing would result in a rapid horizontal movement.

The quick stop was very bad, again because of the wing-down attitude.

PILOT B PR = 10 L_δ = 0.95

Vehicle has a very strong oscillatory tendency laterally. Would have liked a higher control sensitivity but it was so easy to get into an overcontrol and oscillatory situation that the value selected was compromised.

In the air taxi around the square there was PIO, altitude-control difficulty, and difficulty staying over the line. Controlled lateral velocity fairly well but hovering was fair to poor.

In the turn over a spot there was difficulty with lateral drift. Bank angle was fairly high. The turns were made quite slowly in discrete steps. Could not do it quicker because of the oscillation laterally. Hover was very poor. Hit the simulator stops and had to start again twice.

The crosswind turns were very rocky. Oscillated all the way around the turn. It took a while to find the right phasing to damp out an oscillation once started.

Could not do anything with any real precision. A landing from a hover would be problematical.

CASE 255

$Y_v = -0.05$		$\lambda = 0.8$
$L_v g = -0.33$		$\omega_n = 0.64$
$L_p = -0.30$		$\zeta = -0.38$
$L_\phi = 0$		$L = 2.00$
PILOT A	PR = A6	$L_\delta = 2.00$

Was able to use high control sensitivity even though damping in roll was provided by the pilot. When lateral cyclic stick was applied to get a roll angle, the stick had to be brought back beyond neutral to stop the bank angle from developing further. The bank angle would build up at an excessive rate, otherwise. Airplane did not respond to gusts.

Performance in the air taxi around the square was good except when backing up and losing sight of the pattern. There was no problem moving laterally because the wings were level to hold over the ground.

The turn over a spot was more troublesome longitudinally than laterally.

The quick stop was easy to perform. In the crosswind turns there was a very objectionable deficiency noticed in that the airplane would not turn with rudder input. This deficiency degraded the airplane from about A3 to A6.

PILOT C PR = U9 $L_\delta = 0.60$

Vehicle was difficult to fly and required almost total concentration on the lateral axis just to control the vehicle. With the control sensitivity set lower the vehicle was close to being uncontrollable.

In the air taxi around the square there was no trouble initiating motion but it was difficult to stabilize and hold a preselected rate of movement because of overcontrolling in the lateral axis. Had difficulty stopping precisely and coming to a hover at the corners because of excessive attitude changes in roll. Stayed fairly close to the ground-track limit but it required considerable pilot effort.

The turn over a spot was not too difficult. The tendency to develop pilot-induced oscillations could be controlled by small lateral inputs.

An excessive amount of time was required to establish a hover after completing the crosswind turns. Overshot considerably on the first turn. Had difficulty in establishing heading in position over the spot after the turns. The attitude in precision hover was adequate for a vertical landing. No excessive bank angles were required to correct for wind but the constant, rather large inputs on the stick would make a landing very difficult, particularly in any crosswind.

CASE 255 (Continued)

Did not stop as quickly as desired in the quick stop because it seemed evident that a PIO would result and the simulator would hit the stops.

There was not too much difficulty holding altitude during the maneuvers but there was trouble with heading control. Control activity for all the maneuvers was very high. There was an unstable feeling throughout the flight. Felt divergent in the lateral axis. The longitudinal and height dynamics did not affect the evaluation.

CASE 256

$Y_v = -0.05$ $L_\phi = 0$

$L_p = -1.00$ $\omega_n = 0.52$

$\lambda = 1.2$ $\zeta = -0.17$

$L_v g = -0.33$

PILOT B PR = A4-1/2 $L_\delta = 0.70$

With a higher control sensitivity there seemed to be a tendency toward PIO and overcontrolling. For most of the maneuvers the sensitivity should have perhaps been a little higher.

Was able to stabilize the rate of movement fairly well in the air taxi. Achieved a hover in a reasonable length of time if not as quickly as desired. This was a fairly level roll configuration. Attitude changes were only in pitch. There was a lag in the longitudinal control response which affected the precision of longitudinal positioning and hence the overall ability to hover.

Could obtain a fairly good hover in the turn over a spot but it took quite a bit of time. The rudder sensitivity should have been a little higher.

The crosswind turns were pretty good. Could get reasonably close to position in a fairly short time but final longitudinal adjustments caused trouble because of a lag in the response. Precision hover was only fair. Lateral attitude displacements were fairly small about the wings-level condition. It was probably adequate for a vertical landing. Control activity was moderate.

The quick stop was no problem. There was some difficulty in establishing a hover at the end. This was partly due to the lack of a good visual reference in the part of the visual display in which the maneuver ends. Height control in the quick stop was excellent.

Height control in general was within limits. Longitudinal dynamics did enter the evaluation.

PILOT C PR = A6 $L_\delta = 0.49$

The response was slow and there was a tendency to overcontrol in the lateral axis. At a higher control sensitivity there was a definite PIO tendency, so sensitivity was reduced; but at the setting selected, the response was not really adequate.

In the air taxi around the square there was no difficulty initiating motion or stabilizing and holding the preselected rate of movement. However, it took too much time to stop precisely and come to a hover.

CASE 256 (Continued)

No excessive attitude changes were required either in pitch or roll. The ground-track limits were probably exceeded due to overcontrolling in the lateral axis.

Stayed fairly well in position in the turn over a spot. Stick activity was very high and there was some difficulty with lateral control.

After completing the crosswind turns it took an excessive amount of time to come to a hover. There were no overshoot or undershoot tendencies. Control activity was high. Control power was fairly low but could not be increased without getting into PIO. Once in position there was not much difficulty for a vertical landing but it would take a great deal of pilot attention.

Could not stop as quickly as desired in the quick-stop maneuver. Excessive attitude changes were not experienced but they might be to stop in a short time. There was no difficulty in holding heading. Control motions were excessive.

Height control did not make the maneuvers more difficult.

CASE 257

$Y_v = 0.05$ $L_v g = -0.33$

$L_p = -2.00$ $L_\phi = 0$

$\lambda = 2.1$ $\omega_n = 0.39$ $\zeta = -0.03$

PILOT B PR = A3 $L_\delta = 0.82$

Could accomplish the task quite well with this configuration with reasonable pilot effort.

The air taxi around the square seemed to come out pretty well. Could probably do a little more precise task if the velocities, both lateral and longitudinal, were cut down. Hover was pretty good at each point. There was a slight amount of drifting, with the longitudinal axis more trouble than the lateral. Initiation of motion was acceptable. Was able to stabilize on velocities and stop fairly precisely. There were no excessive attitude changes in roll. Task did not require a lot of pilot effort to do a good job.

Was able to do the turn over a spot fairly well. There was a slight amount of drifting. Rudder control was certainly adequate and heading-hold was good. Hover was fairly good.

The crosswind turns were quite good. Precision of hover was fairly good although there was some drifting. It was certainly adequate for a vertical landing. Control activity was very light in the hovers.

The quick stop was quite good. Stopped quickly without excessive attitude changes. Could hold heading and hold drift to a small amount.

Height control was good throughout.

PILOT C PR = A2-1/2 $L_\delta = 0.47$

Vehicle was easy to fly. It was a low frequency system but comfortable. There was no PIO tendency.

In the air taxi around the square it was very easy to initiate motion in all directions. Had no trouble holding the preselected rate of movement or in stopping precisely over the corners of the square. There were no excessive attitude changes necessary in either pitch or roll. Was able to stay fairly close to the ground-track limits. Rudder response seemed quite sensitive and there was no difficulty holding heading during any of the maneuvers.

Remained fairly close to the center in the turn over a spot. There was no difficulty initiating a turn or in holding a preselected turn rate. Overshot once or twice stopping on preselected headings.

CASE 257 (Continued)

Overshot slightly in the crosswind turns although the rollout was on the desired heading. Control activity was light to moderate and control power seemed adequate. This vehicle would be excellent for a vertical landing from a hover.

Stopped as quickly as desired in the quick-stop maneuver. Excessive attitude changes were not required. There was no difficulty in holding heading or altitude during the maneuver. Control motions were light to moderate.

Height control requirements did not make any maneuver more difficult. Longitudinal and height dynamics did not affect the evaluation.

The fact that there was no feel in the stick was mildly unpleasant.

CASE 258

Y_v	=	-0.2
$L_v g$	=	-0.33
L_p	=	-0.60
L_ϕ	=	0

λ	=	1.0
ω_n	=	0.58
ζ	=	-0.28

PILOT A PR = A5 L_δ = 1.24

For the desired control sensitivity the airplane had a slight tendency to be oscillatory in the lateral axis. The sensitivity was reduced to remove the oscillation but the stick movements were then larger than desirable.

In the air taxi around the square the airplane seemed to be markedly affected by transverse gusts which moved the whole airplane sideways in an objectional manner. There were no excessive attitude changes in roll. Rudder control was satisfactory.

In the turn over a spot there was more trouble longitudinally than laterally in maintaining position.

Had difficulty with precision hover because of transverse motion due to gust input. The quick stop was satisfactory and the crosswind turn did not present any particular problem.

PILOT C PR = A4 L_δ = 0.47

Increased control sensitivity gave a very definite tendency to overcontrol. There was a slight tendency to overcontrol with the sensitivity selected. Vehicle was divergent or not well damped.

There was no difficulty initiating motion in the air taxi around the square. No excessive attitude changes were required and it was easy to stay within the ground-track limits.

Stayed very close to the desired spot in the turn over a spot. Some moderate pitch inputs were required going around.

The crosswind turns worked out well. There was no excessive time used to accomplish the maneuver and no overshoot or undershoot tendency. Control activity was light to moderate and there was adequate control power. Precision hover was easy and excellent for a vertical landing although there was slight overcontrolling laterally.

The quick stop worked out well. Overshot somewhat but it was easy to come to a hover after the maneuver.

Height control requirements did not make the maneuver more difficult.

SECOND SIMULATION

OBJECTIONABLE FEATURES

1. Attitude required to compensate for wind was too steep. Too great an attitude change was required to initiate motion or to maneuver.

PILOT A	:	130, 140, 141, 145, 151, 160, 161 225, 240, 249, 260
PILOT B	:	128, 140, 141, 143, 147, 151, 153, 154, 159, 161 232, 233, 234, 249, 254, 259
PILOT C	:	105, 127, 137, 140, 141, 147, 150, 159, 160 232, 260, 261

2. Airplane tended to be oscillatory, to have inadequate damping, to be unstable, to be prone to pilot-induced oscillations, or to get away.

PILOT A	:	224, 263, 264
PILOT B	:	116, 153, 162 219, 232, 249, 254, 262, 264
PILOT C	:	112, 122, 125, 155, 158, 162, 163 206, 212, 218, 237, 255, 259, 262, 263

3. Response was too high-frequency, too quick, or too abrupt.

PILOT A	:	141 204
PILOT B	:	106, 116, 128, 147, 151, 154, 162, 164
PILOT C	:	105, 107, 137, 141

4. Airplane responded to gusts too much.

PILOT A	:	102, 112, 115, 140, 141, 155, 163, 164 219
PILOT B	:	106, 116, 153

5. There was a tendency to overcontrol.

PILOT B	:	106, 157 259
PILOT C	:	105, 125, 141, 155, 158 206, 232, 259

6. There was difficulty in establishing a precision hover.

PILOT B	:	116, 140, 151, 153, 157, 159 232, 233, 262

7. Response was too slow or too sluggish.

PILOT A	:	115 261
PILOT B	:	159 219, 235, 259, 261

OBJECTIONABLE FEATURES (Continued)

8. It was difficult to perform the maneuvers with precision.

PILOT A : 147
PILOT B : 262
PILOT C : 237, 255, 262

9. Constant attitude corrections, high control activity, or excessive pilot effort were required.

PILOT B : 159, 161 164
PILOT C : 162

10. There was apprehension about losing control.

PILOT A : 219
PILOT B : 264
PILOT C : 255, 263

11. It was difficult to maintain an accurate ground track.

PILOT C : 232, 259, 260, 263

12. Airplane was uncomfortable to fly.

PILOT C : 102, 122

FAVORABLE FEATURES

1. It was easy to maintain the ground track or position over the ground.

   PILOT C : 105, 107, 112, 122, 125, 137, 150, 155, 158, 160, 162
   206, 212, 218

2. Performance of the tasks was reasonably good.

   PILOT A : 158
   PILOT B : 106, 116, 143, 147, 157, 159, 164
   219, 249, 257
   PILOT C : 102
   261

3. Airplane was well-damped. There was no tendency for it to oscillate or get away. There was no PIO tendency.

   PILOT A : 147, 160, 161
   240, 249, 261
   PILOT B : 116, 140
   232
   PILOT C : 127
   260

4. Airplane required very little nose-down or wing-down attitude to compensate for wind.

   PILOT A : 112, 115, 158, 164
   204
   PILOT B : 219
   PILOT C : 107

5. A reasonable hover could be achieved. It was easy to make a transition from translation to hover.

   PILOT B : 162
   PILOT C : 140, 147, 150, 158, 160

6. The response to the controls was good, smooth, or precise.

   PILOT B : 141
   232
   PILOT C : 127, 160
   261

7. The response to gusts was good.

   PILOT A : 151
   261

FAVORABLE FEATURES (Continued)

8. The frequency of the airplane's response was good.

   PILOT A : 161
   240

9. There was no tendency to overcontrol.

   PILOT C : 150

CASE 102

$X_u = -0.05$ $\lambda = 0.5$

$M_u g = 1.00$ $\omega_n = 1.50$

$M_q = -1.05$ $\zeta = 0.20$

$M_\theta = -2.50$

PILOT A   PR = A4-1/2 $M_\delta = 1.25$

Airplane only required about 2 degrees of nose-down pitch to maintain a hover into the wind, but it had an annoying, jarring response to gusts. Performance was adequate and pilot workload was not excessive.

The turn over a spot was sloppy. There was a tendency to wallow. Could perform the crosswind turn readily and come to a hover wherever desired. The quick stop did not require an excessive attitude change but it was necessary to perform the maneuver smoothly to avoid hitting the simulator limits. There was no tendency to lose control of the airplane. There was no particular problem with height control.

PILOT C   PR = A4 $M_\delta = 0.46$

With a lower control sensitivity the stick movements were too large.

There was no difficulty initiating motion in any direction and no difficulty stabilizing and holding a preselected rate of movement. It was fairly easy to stop precisely and come to a hover at the corners, although in the transition from translation to hover there was an uncomfortable, unstable feeling. There was little difficulty remaining within the ground track. Rudder response seemed adequate.

Stayed fairly close to the spot in the turn over a spot. Attitude control was easy, although there was a slight tendency to overcontrol.

The crosswind turns worked out well without difficulty establishing a position over the spot after rollout. Control activity was moderate and control power adequate.

It was easy to maintain position in the precision hover. There were no excessive attitudes or rates developed in compensating for wind.

CASE 102 (Continued)

In performing the quick stop, the vehicle stopped very fast. There were no excessive attitude changes required and no trouble holding heading or altitude. Control motions were moderate with a slight tendency to overcontrol.

Lateral-directional or height dynamics did not affect the overall evaluation.

CASE 105

X_u	= -0.05	λ	= 1.00
$M_u g$	= 1.00	ω_n	= 1.04
M_q	= -1.55	ζ	= 0.29
M_θ	= -1.60		

PILOT C   PR = A5 M_δ = 0.46

Airplane was difficult to fly and required a great deal of attention to fly precisely.

In the air taxi around the square there was no difficulty initiating motion in any direction and no difficulty in stabilizing or holding a preselected rate of movement. Some difficulty was experienced in stopping precisely and coming to a hover at the corners. This resulted in straying off the desired ground track excessively. Attitude changes in pitch, although not excessive, were slightly more than optimum. There was no difficulty remaining within the ground track when flying a straight leg but it was difficult to do so when changing from translation to hover. Rudder response was adequate and there was no difficulty holding headings throughout all maneuvers.

In the turn over a spot, there was some difficulty remaining over the spot. There was difficulty with attitude control in both pitch and roll. There was no difficulty in stabilizing or holding a preselected turn rate and no difficulty in stopping at a preselected heading.

There was no overshooting or undershooting in the crosswind turns, although there was some trouble in establishing the desired position over the ground after the maneuvers. Control activity was slightly more than moderate due to overcontrolling longitudinally. Once established in a precision hover there was no difficulty maintaining the hover. It was very easy to hold position over the ground, although while in the hover the gusts seemed to affect the vehicle more than would be normally expected. The vehicle could be landed vertically.

The vehicle stopped very quickly in performing the quick-stop maneuver. A very steep attitude was used to perform this maneuver without loss of control. There was no difficulty in holding heading or altitude. Control motions were moderate to heavy due to overcontrolling.

Height control requirements did not make the maneuvers more difficult. Lateral-directional dynamics did not affect the evaluation of the longitudinal dynamics. There was an abrupt response to control inputs because of the level of control sensitivity.

CASE 106

X_u	= -0.05	λ =	1.0
$M_u g$	= 1.00	ω_n =	1.03
M_q	= -1.15	ζ =	0.10
M_θ	= -1.20		

PILOT B   PR = A3 M_δ = 0.73

With the control sensitivity selected, the initial response was rather abrupt. It was not unacceptable, but it was somewhat annoying. Overall, the performance with this configuration seemed to be good.

In the air taxi around the square, there seemed to be a lag in initiating motion and it required a fair amount of control input to get the aircraft moving. However, heading and rate of motion could be stabilized and a stop made at the corners. A good steady-state hover took a fair amount of concentration. Could remain within the ground track pretty well except when backing up. The control feel was okay although it was always evident that this was a displacement-input system with no force feedback. The airplane response to rudder input was not very snappy. It was okay but a better response would have been preferred.

The turn over a spot could be performed while remaining over the spot quite well as long as the yaw rate was within reasonable limits. Attitude control was okay. This did not seem to be a very high drag configuration but it probably had some M_u which was causing some small-amplitude pitch oscillations. There was no difficulty stabilizing, holding heading, holding turn rate, or stopping.

The crosswind turns worked out quite well. There seemed to be good control and no real tendencies for overshoot or undershoot. A hover adequate for landing could be made rather easily. The precision of hover was quite good, although a fair amount of pilot effort was required to maintain it.

It was not possible to get the airplane moving fast enough to perform a real quick stop. A gentle stop was made with good precision. Altitude control performance was quite good.

There were no strong objectionable features and a very good precision job could be done.

CASE 107

X_u = -0.05 λ = 1.5

$M_u g$ = 1.00 ω_n = 0.85

M_q = -2.25 ζ = 0.35

M_θ = -1.81

PILOT C PR = A3 M_δ = 0.32

Airplane was easy to fly. There was some roughness to the control response and the control sensitivity had to be turned down to a fairly low level.

There was no difficulty in the air taxi around the square in initiating motion, stopping precisely, or coming to a hover at the corners. There were no excessive attitude changes necessary in either pitch or roll. Taxiing was maintained fairly close to the ground track. Rudder control was good.

The turn over a spot was performed staying very close to the spot. There was no trouble stopping at a preselected heading.

The crosswind turns went well without taking an excessive time to accomplish. There was no trouble in establishing heading in position over the spot after completion of the turns. Once established in precision hover, it was easy to maintain. There were no excessive attitude or angular rates necessary to compensate for wind. The airplane was adequate for a vertical landing. Control activity in the turns and hover was light to moderate. Control power was adequate.

The vehicle was stopped very fast in quick-stop maneuver with no excessive attitude changes required. There was no difficulty in holding altitude. Control motions during the maneuver were light.

Lateral-directional and height dynamics did not affect the evaluation.

CASE 112

$X_u = -0.05$ $\lambda = 2.5$

$M_u g = 1.00$ $\omega_n = 0.64$

$M_q = -2.45$ $\zeta = 0$

$M_\theta = -0.28$

PILOT A PR = A3 $M_\delta = 1.38$

Airplane was very easy to fly. It required very little pitch-down attitude to hold into the wind. Damping was satisfactory. Everything seemed to be satisfactory on this airplane. Except for the quick-stop maneuver, the airplane was really quite good.

There were no big problems in the air taxi around the square. The vehicle could stop precisely and hover at the corners satisfactorily.

The turn over a spot was really no problem at all.

The crosswind turn was satisfactory once a control technique for applying rudder was learned. There was ample control power. Precision hover was no problem because of the small amount of pitch-down attitude.

Could not stop as rapidly as desired in the quick-stop maneuver because pulling the nose up to stop as soon as possible caused the simulator to hit its limits.

PILOT C PR = A4 $M_\delta = 0.65$

The response was very jerky, perhaps because the sensitivity was up a little high.

In the air taxi around the square there was some trouble initiating motion and overcontrolling longitudinally. Could stop precisely and come to a hover at the corners. No excessive attitude changes were required in either pitch or roll. Stayed fairly close to the ground track. Rudder response was adequate and there was no trouble in holding heading.

The turn over a spot was performed fairly close to the desired spot. Some moderate attitude changes were necessary, mostly in pitch. Control harmony felt bad when changing from a pitch

CASE 112 (Continued)

correction for wind to a lateral correction. There was no difficulty in stopping at a preselected heading.

The crosswind turns were accomplished fast. There was no trouble in establishing heading or position over the spot after rollout. Control activity was moderate to heavy and caused a certain amount of overcontrol. Control power was adequate. Once established in a precision hover, there was not too much trouble maintaining position. The attitude was such that it would be adequate for a vertical landing.

The quick stop worked out well, although an excessive attitude change was required because of the high airspeed built up. Overshooting occurred and the simulator hit the stops. There was no trouble holding heading or altitude and control motions were moderate to heavy.

The lateral-directional and height dynamics did not affect the evaluation except for the fact that the lateral system was poorly matched to the longitudinal.

There was a feeling of low-frequency divergence but not a feeling of PIO because the response was slow.

CASE 115

X_u = -0.05 λ = 6.0

$M_u g$ = 1.00 ω_n = 0.41

M_q = -5.95 ζ = 0.02

M_θ = 0

PILOT A PR = A5 M_δ = 1.96

The gust response was sharp and annoying in this airplane. Also, the response to pitch control seemed to be out of phase with the stick. The response seemed to be well-damped, but it was too slow.

There was no real problem in the air taxi around the square. Performance seemed to be good. Only 1 or 2 degrees nose-down was required to hold into the wind which was not bad, although none would be preferable. There was trouble with lateral translation. The airplane seemed to wallow or slide laterally.

There was no particular problem with the turn over a spot. The crosswind turn seemed to best be flown by initiating with an angle of bank and rudder, then taking the bank out and skidding around with the rudder. The precision hover was no problem except for translating laterally.

The quick stop was satisfactory if the limitation of the simulator was realized and the nose not brought up too high.

CASE 116

$X_u = -0.05$ $\lambda = 3.1$

$M_u g = 1.00$ $\omega_n = 0.57$

$M_q = -3.00$ $\zeta = -0.05$

$M_\theta = 0$

PILOT B PR = A5 $M_\delta = 0.91$

The control sensitivity chosen was a compromise between a value which resulted in an initial abruptness of response and one which met the requirements for hover. The selection may have been a little on the high side. There were constant pitch inputs required for hovering. The airplane was responding to gusts and gave the impression of dynamic instability at a rather low frequency. The drag characteristics were probably average. It took a couple of degrees nose-down to offset the head wind.

In the air taxi around the square, it was possible to initiate motion, stabilize, and stop reasonably well. Hover was moderately difficult. It took a moderately large amount of attitude change to stop from a reasonable forward velocity. Ability to remain within the ground track was fair. Control felt a little touchy because of the abruptness in response.

The turn over a spot could be performed reasonably well with sufficient concentration. Very large attitude changes were not required. More lateral attitude change was required than longitudinal. Rudder control was acceptable.

The crosswind turns took a moderate amount of time to perform and there was a bit of a problem establishing a hover but it could be done. There was constant attitude control activity which seemed to be low to moderate in amplitude. The precision of hover was not as good as it should have been although it was adequate for a vertical landing.

The quick stop was not performed as fast as it should have been. Quite a bit of forward speed was picked up and a fairly large attitude change made but the deceleration was not as fast as would be preferred. There was overshooting and it required work to get to a hover. Height control required moderate activity.

Lateral-directional dynamics were noticeable in the hover. There was a certain amount of annoying lateral drift which was coupled with constant pitch-attitude hunting.

CASE 116 (Continued)

The tasks could be performed reasonably well and the airplane never felt as if it would get away but small inputs were required all the time.

CASE 122

$X_u = -0.2$ $\lambda = 0.3$

$M_u g = 0.33$ $\omega_n = 1.82$

$M_q = -0.30$ $\zeta = 0.06$

$M_\theta = -3.30$

PILOT C PR = U7 $M_\delta = 0.43$

The airplane seemed to be on the verge of a pilot-induced oscillation all the time. However, the frequency seemed to be so high that there was not much problem. The control sensitivity was set at a level to give as smooth a response as possible. A setting any lower would not provide enough control to counteract the wind.

In the air taxiing around the square there was no trouble initiating motion or holding a preselected rate of movement. It was easy to stop at the corners. Constantly throughout the maneuver the airplane was pitching up and down probably 2 or 3 degrees. The ground track was maintained fairly closely except on the final leg.

Got off the spot about 20 feet in the turn over a spot due to constant overcontrolling longitudinally. The frequency was such that it caused overcontrolling by pumping the stick back and forth. The stick movments were not large so the control sensitivity was probably high enough.

The crosswind turn worked out real well. Was able to establish a heading in a position over the spot after the turn, although control activity was high due to constant porpoising longitudinally. Once established in a hover, it was easy to maintain although pilot effort was high and would be wearing in a real airplane. It would be hard to land this vehicle vertically because of the bobbing back and forth.

The quick-stop maneuver resulted in about four overshoots and there was an excessive attitude change because of overcontrolling. Control motions were moderate to heavy.

Lateral-directional and height dynamics did not affect the evaluation.

CASE 125

$X_u = -0.2$ $\lambda = 0.5$

$M_u g = 0.33$ $\omega_n = 1.03$

$M_q = -0.30$ $\zeta = 0$

$M_\theta = -1.00$

PILOT C PR = A6 $M_\delta = 0.43$

Vehicle appeared to be either lightly damped or divergent.

There was no difficulty initiating motion in any direction in the air taxi around the square. There was some trouble in holding a preselected rate of movement because of constant overcontrolling longitudinally. There was no trouble in stopping precisely at the corners, although in coming to a hover there was constant pushing of the stick back and forth and overcontrolling. There were no excessive attitude changes required and the ground-track limits were maintained fairly closely. Rudder control response and sensitivity were adequate, although the yaw rate was lower than what would be desirable in a real airplane.

In turning over a spot there were deviations as much as 25 feet from the desired ground position. This was due to overcontrolling and not due to the attitudes necessary to maintain position. There was no difficulty initiating a turn rate or holding the rate.

The crosswind turns went quite well without overshoot or undershoot tendencies. There was no trouble establishing a heading or position after rolling out of the turn, although high control activity longitudinally made it an uncomfortable system to fly. Precision hover was a bit difficult to establish, but once in position over the spot it was easy to maintain. The vehicle would be marginally adequate for a vertical landing because of the constant nose up-and-down action that was inadvertently put into the system.

In the quick stop there was one overshoot that went to the limits of the simulator. There was no difficulty in establishing heading or altitude. Control motions were heavy.

Height control requirements did not make the maneuvers more difficult.

CASE 127

$X_u = -0.20$ $\lambda = 1.00$

$M_u g = 0.33$ $\omega_n = 0.69$

$M_q = -1.30$ $\zeta = 0.36$

$M_\theta = -0.71$

PILOT C PR = A4 $M_\delta = 0.38$

Vehicle was easy to fly. Control sensitivity selected gave an adequate and smooth response.

In the air taxi around the square, there was no difficulty initiating motion except that the pitch angle required was very steep into the wind. There was no difficulty in holding a preselected rate of movement. A stop could be precisely made at the corners and a hover established. There was an excessive attitude change necessary longitudinally in order to compensate for wind. Ground-track limits were maintained fairly closely. Rudder response seemed very slow. The turn rate just didn't feel adequate.

The turn over a spot was performed fairly close to the spot despite the large longitudinal changes necessary to compensate for the wind. There was no difficulty stopping on a preselected heading.

The first crosswind turn resulted in an overshoot; the second, an undershoot. This seemed to be just due to pilot technique. There was no difficulty in establishing heading and position over the spot. Control activity was light to moderate and control power adequate. Precision hover revealed the main deficiency with this vehicle and that was the steep attitude necessary to compensate for wind. Control activity was light in the hover. There might have been some difficulty in performing a vertical landing in this airplane due to the steep attitude.

In performing the quick stop, there were excessive attitude changes in initiating motion and in translating into the wind. There was no problem in holding heading or altitude. Control motions throughout the maneuver were moderate.

Lateral-directional and height dynamics did not seem to affect the evaluation. There was no tendency toward pilot-induced oscillations.

CASE 128

$X_u = -0.20$ $\lambda = 1.00$

$M_u g = 0.33$ $\omega_n = 0.61$

$M_q = -0.80$ $\zeta = 0$

$M_\theta = -0.21$

PILOT B PR = U8 $M_\delta = 1.06$

Selection of control sensitivity was difficult. The sensitivity selected gave a fairly abrupt initial response but a lower value could not be used because of the requirement for large attitude changes and because there would be too much lag in the system. A fairly wide band of sensitivities could have probably been chosen with about the same results.

In the air taxi around the square the initiation of motion was slow. It was not possible to really stabilize the rate of movement, stop precisely, or hover. Attitude changes were excessive. Ability to remain within the ground track was not too bad. The rudder control was sluggish.

In the turn over a spot, it was not easy to stay close to the spot. Could never really hover very well. There was some tendency to overcontrol in pitch. The response was abrupt.

It was disconcerting to make the crosswind turns with a very nose-low attitude into the wind. Hover was very poor all the time. There was a tendency to overcontrol in pitch and holding position was very difficult. The airplane would be very marginally adequate for a vertical landing.

Stopped quickly in the quick-stop maneuver but it involved anticipation of the required attitude changes.

There was an extreme problem trying to maintain altitude. It felt as if something was malfunctioning.

The lateral-directional dynamics probably did enter into the evaluation some. They were evident in the hover.

The airplane had a tendency to diverge and it required constant attention.

CASE 130

$X_u = -0.2$ $\lambda = 1.5$

$M_u g = 0.33$ $\omega_n = 0.52$

$M_q = -1.60$ $\zeta = 0.29$

$M_\theta = -0.40$

PILOT A PR = A5 $M_\delta = 1.10$

An excessive nose-down attitude was required to hold into the headwind. Response was well-behaved; there was no tendency for the airplane to get away.

Performance in the air taxi around the square was acceptable. There was a coordination problem in the turn over a spot. There was no real trouble in the crosswind turn or in the quick stop except that it was difficult to get up any speed. It required lowering the nose to an objectional level.

The response to gusts in pitch was very low.

CASE 137

$X_u = -0.20$ $\lambda = 0.50$

$M_u g = 1.00$ $\omega_n = 1.90$

$M_q = -1.80$ $\zeta = 0.40$

$M_\theta = -3.98$

PILOT C PR = A5 $M_\delta = 0.51$

Response was very uncomfortable with the control sensitivity turned up and it was turned down to where stick movements were very large.

The air taxi around the square was flown very slowly all the way around. There was no trouble initiating motion, and no difficulty in stabilizing and holding a preselected rate of movement. Stopped easily very precisely at the corners and stayed fairly close to the ground track. Excessive attitude changes were required in pitch into the wind; too much to make flying comfortable. Would prefer a higher yaw rate.

There was difficulty remaining over the spot in the turn over a spot due to the large attitude changes necessary to compensate for the wind.

The crosswind turns worked out well without overshoot or undershoot tendency. Heading was established easily after the turn, Position for the hover was achieved immediately after rollout. It was fairly easy to establish a precision hover and once established it was easy to maintain. Attitude was very marginal for a vertical landing. Control activity was light to moderate.

Could not get up enough translational speed to evaluate the quick-stop maneuver well. This was due to the fact that with the stick all the way forward, acceleration was very low.

Lateral-directional and height dynamics did not affect the evaluation although there was overcontrolling laterally.

CASE 140

$X_u = -0.20$ $\lambda = 1.00$

$M_u g = 1.00$ $\omega_n = 1.20$

$M_q = -2.80$ $\zeta = 0.50$

$M_\theta = -2.25$

PILOT A PR = A5 $M_\delta = 1.27$

There was too much pitch-down attitude to hover into the wind. The airplane was a little too sensitive to gust input in pitch but the response was satisfactory. The airplane handled all right. The air taxi and the turn over a spot were affected by the pitch attitude and by the annoyance of the gusts but not severely so.

The crosswind turn, precision hover, and quick stop were all right.

PILOT B PR = A6 $M_\delta = 0.89$

The selection of control sensitivity was a compromise. Choosing too high a sensitivity generated an abruptness in response. On the other hand, a reasonably high value was needed to be able to hover.

In the air taxi around the square, there was some lag in the initiation of motion. The configuration seemed to have high drag and was fairly nose-down into the wind. Motion could be stabilized fairly well but stopping precisely was difficult. There was some overcontrolling. Hover was only fair to poor. Ability to make good the ground track was only fair. Rudder control was sluggish.

The turn over a spot was somewhat poor. Rudder control was adequate. The crosswind turns could be performed but not very rapidly. There was difficulty in making small corrections to get over the spot and in trying to achieve a hover. The hover was not very good. There was a lot of control activity all the time. Hover would have been questionably adequate for a vertical landing.

The quick-stop maneuver required attitude change but the stop could be made quickly. Control motions were moderate but achieving a steady hover was somewhat difficult. Heading and altitude could be held.

CASE 140 (Continued)

The lateral dynamics were certainly obvious and probably aggravated the situation. There was no feeling that the airplane would oscillate or diverge.

PILOT C PR = A5 M_δ = 0.38

It was easy to air taxi around the square, and easy to stabilize and hold a preselected rate of movement. Had no trouble stopping at the corners, although there was a little difficulty in maintaining the limits of the ground track. Rudder response was slow but adequate. The control sensitivity was set fairly low and may have been responsible for a somewhat sluggish response.

In the turn over a spot there was difficulty in remaining over the spot. This was due to the very steep attitude necessary to compensate for the wind.

There were no overshoots or undershoots in the crosswind turns. There was no difficulty in establishing a heading or position after rolling out of the turns. Control activity was heavy; control power, adequate. There was no difficulty in establishing and maintaining a precision hover, although the attitude was a little too steep to correct for wind. It was marginal whether this vehicle would be adequate for a vertical landing.

The vehicle stopped quickly in the quick-stop maneuvers although there was overcontrolling laterally throughout the maneuver. Control motions were moderate to heavy.

Lateral-directional dynamics perhaps did affect the evaluation because of difficulty maintaining a wings-level attitude throughout the flight.

Control harmony was poor. It was easy to change from a translation to a hover.

CASE 141

$X_u = -0.20$ $\lambda = 1.00$

$M_u g = 1.00$ $\omega_n = 1.15$

$M_q = -1.40$ $\zeta = 0.26$

$M_\theta = -1.65$

PILOT A PR = A6 $M_\delta \doteq 1.17$

There was an undesirable amount of nose-down attitude into the wind and a lot of response to gusts. The frequency was a little too high and the response too sudden.

The air taxi around the square was reasonably good but the pitch response to gusts and the hovering attitude resulted in the pilot working too hard.

The turn over a spot required hard work in order to maintain the turn. The quick stop and the crosswind turns were okay.

PILOT B PR = A5 $M_\delta = 0.70$

The control sensitivity was set low enough to reduce the initial abruptness of response but high enough to give reasonable control. However, the control motions were rather large and more sensitivity would have been preferred to get the airplane moving, but the response would then have been too abrupt. This was a high drag configuration and rather large pitch attitude changes were required for small corrections.

In the air taxi around the square, there was quite a bit of cyclic control activity but it was not excessive. A pretty good steady-state rate could be established but it was necessary to work at it to keep the airplane moving into the wind. Was not really able to stop precisely and there was a tendency to overshoot. Hover could be attained with just a moderate amount of control activity. Ability to remain within the ground track was fair to poor. Rudder response was a little sluggish, but there was no trouble holding a heading.

Rather large attitude changes were required in the turn over a spot. The attitude when heading downwind was particularly uncomfortable. There was substantial drifting off the spot and it took quite a bit of effort to bring the airplane back. The rudder control was adequate to initiate turns, stop on preselected headings, and hold headings.

CASE 141 (Continued)

Undershot the spot following the crosswind turns, but came to a reasonable hover. The precision of hover was mostly poor, but adequate for a vertical landing. Control activity was moderate to heavy.

Quick stops could be performed quickly. Attitude changes required were rather small and control motions only moderate. Could hold heading but height control was sloppy.

Lateral-directional dynamics added to the problem and had some effect on the evaluation.

PILOT C PR = A5 $M_{\delta} = 0.50$

The vehicle was difficult to fly but could be learned. The response to control inputs was jerky as though it were a high-frequency system. The control sensitivity should perhaps have been turned down but insufficient control response would have resulted.

In the air taxi around the square there was no difficulty initiating motion in any direction, although the correction for wind was very steep when translating. Some difficulty was experienced stopping precisely and coming to a hover but this became easier with practice. The vehicle did remain within the desired ground track limit.

In the turn over a spot, there was only slight difficulty remaining over the spot and no difficulty initiating a turn rate or holding a preselected rate.

The crosswind turns were accomplished in a minimum of time. There was a slight tendency to overshoot but no difficulty in establishing heading or position over the spot after completing the turns. Control activity was moderate. Once established in a precision hover, it was easy to hold although the gusts did affect the vehicle excessively. Control activity in the hover was light to moderate.

In performing the quick-stop maneuver, the vehicle stopped quickly with no overshoots and only a slightly excessive attitude change. Control motions were moderate during the maneuver.

Lateral-directional dynamics detracted slightly from the longitudinal dynamics in that the systems were not well-matched. Height control was a little sloppy.

CASE 143

X_u	$= -0.20$	λ	$= 1.50$
$M_u g$	$= 1.00$	ω_n	$= 0.94$
M_q	$= -2.10$	ζ	$= 0.43$
M_θ	$= -1.67$		

PILOT B PR = A4½ $M_\delta = 0.79$

This was a high-drag configuration requiring quite large attitude changes. Selection of control sensitivity was a compromise. Setting it up high resulted in a high initial response.

In the air taxi around the square, there was some difficulty initiating motion due to a lag in response. Holding the rate of movement was not good nor was the precision of stopping. There was a tendency to stop too soon going into the wind. Ability to stay within the ground track was fair.

The turn over a spot was fairly good. There was a tendency to get behind in making the necessary attitude changes going around the spot.

The crosswind turns resulted in undershooting and reasonably hard work was required to get back to the spot. A hover could be achieved which was adequate for a vertical landing. Control activity in the turns and in the hover was moderate to heavy.

Could stop as quickly as desired in the quick-stop maneuver. Altitude change was not great. Could hold heading and come to a reasonable hover.

Height control was somewhat of a problem. This may have been due to the time spent flying the other axes. Secondary dynamics probably downgraded the overall rating.

CASE 147 (Continued)

PILOT C PR = A6 M_δ = 0.43

The control sensitivity was set at a value to give a response that was not too abrupt. The vehicle was fairly well-damped and not too difficult to fly.

There was no difficulty taxiing around the square or hovering at the corners. The attitude required to counteract the wind was a little excessive. There was no difficulty in remaining fairly close to the ground track. Rudder response seemed very slow and sloppy.

In the turn over a spot, the rather large pitch changes required to counteract the wind resulted in the vehicle getting off the spot somewhat.

There was overshooting in the crosswind turns. This seemed to be due to what felt like a low yaw rate. There was no difficulty establishing a heading in position over the spot. Control activity was moderate but there was some overcontrolling in the lateral axis. Precision hover, once established, was easy to maintain although the attitude was such that a vertical landing would be difficult to perform.

In the quick-stop maneuver there were about two overshoots. There was no difficulty in holding heading. Control motions required were moderate.

Lateral-directional dynamics did not affect the evaluation. There was trouble with height control throughout the flight.

CASE 147

X_u	= -0.2	λ	= 2.5
$M_u g$	= 1.00	ω_n	= 0.73
M_q	= 1.40		
M_θ	= -1.68	ζ	= 0.48

PILOT A — PR = A6 — M_δ = 1.33

Performance with this airplane was very bad partly due to the nose-down attitude required to hold into the wind. It was a difficult airplane to evaluate. Something was wrong with it but it was hard to sort out.

There was trouble with the air taxi and the crosswind turns.

Airplane was well-damped and the frequency was not too high.

PILOT B — PR = A5 — M_δ = 0.82

A nose-low attitude was required to perform the maneuvers. There was an initial abruptness in pitch response. The control sensitivity was chosen to keep the initial response reasonable.

It was a little difficult to initiate forward motion in the air taxi around the square. Could stabilize and hold a rate of motion fairly well. Attitude changes were somewhat excessive. Ability to remain over the ground track was fair.

There was difficulty in the turn over a spot primarily due to drifting trying to maintain a hover in the downwind direction. Attitude changes around the turn were large. It was a little sluggish initiating a turn, but it was not difficult.

The crosswind turns resulted in undershooting. Reasonably hard work was required to get over the spot. The hover was not really solid. Control activity was moderate to heavy.

The quick stop was pretty good. There was no question about stopping. Altitude and heading were maintained reasonably well.

In general, there was difficulty in maintaining altitude which means that other dynamic situations required more attention. Lateral dynamics did enter into the evaluation somewhat.

CASE 145

X_u	=	-0.2	λ	=	1.5
$M_u g$	=	1.00	ω_n	=	0.87
M_q	=	-1.40	ζ	=	0.06
M_θ	=	-0.62			

PILOT A PR = A6 M_δ = 1.28

The airplane required too much nose-down to fly well and to hover. Pitch response was fast and the gust agitation was noticeable.

During the air taxi around the square, there was an inability to move forward fast enough because of having to have the nose down too far. Altitude control required careful use of the throttle because of the changes in pitch attitude between the forward direction into the wind and the backward direction downwind. It made the whole task more difficult.

There was a lot of trouble in the turn over a spot maintaining altitude. It was extremely difficult to coordinate the turn because of the pitch-attitude change from nose into the wind to nose full downwind.

The crosswind turn was not bad, but it was necessary to get the pitch attitude correct coming into the wind to avoid sliding.

The quick stop was difficult because of the steep attitude required to get up speed.

There was a lot of trouble with height control.

CASE 151

X_u	=	-0.2	λ	=	6.0
$M_u g$	=	1.00	ω_n	=	0.41
M_q	=	-6.00	ζ	=	0.19
M_θ	=	0			

PILOT A PR = A4 M_δ = 1.21

The airplane was nicely damped and was unresponsive to gusts. It responded smoothly, but perhaps with some lagging. The only deficiency was the fact that it required about seven or eight degrees nose-down in the wind. This made coordination of turns difficult.

PILOT B PR = A6 M_δ = 1.41

The control sensitivity selection was a compromise between a sluggish response and a very abrupt responsiveness. The selection was based primarily on the ability to hover.

In the air taxi around the square, it was a little difficult to initiate motion and it was not easy to stabilize at all, particularly going into the wind. Ability to stop precisely at the corners was not good. Excessive attitude changes were required for small corrections in drift. The airplane responded to gusts quite a bit which made it difficult to stay within the ground track. The rudder response was a little sluggish.

The turn over a spot was performed fairly well because of anticipating attitude changes going around the turn. There was a tendency to overcontrol which made the abruptness in response a little more annoying and more noticeable.

The crosswind turns required an excessive amount of time to make small displacement corrections. The hover was uncertain, not a good solid hover, and it required quite a bit of effort. It was adequate for initiation of a vertical landing, however. Control activity was heavy.

The quick stop was performed reasonably well, although there was overcontrolling. The height control gave some trouble. This was the result of not having sufficient time to look at height control.

The lateral drift was bothersome but had only slight effect on the overall evaluation.

CASE 150

X_u	=	-0.2	λ	=	6.0
$M_u g$	=	1.00			
M_q	=	-6.10	ω_n	=	0.44
M_θ	=	-0.77	ζ	=	0.33

PILOT C PR = A5 M_δ = 0.37

The airplane was easy to fly although steep attitude changes were necessary. Control sensitivity was turned down to give a smoothness to the control response.

There was no difficulty in initiating motion or holding a preselected rate of movement around the square. It was quite easy to come to a stop at the corners except for the third leg where translation was backwards and required a very steep nose-down attitude to compensate for the wind in stopping. Stayed fairly close to the ground track. Rudder control was low but adequate.

In the turn over a spot, there was a great deal of difficulty in maintaining position due to the large attitude changes necessary.

The crosswind turns worked out well except for overshooting on the second one due to the low yaw rate available. There was no difficulty in establishing heading after the turns but there was trouble in rolling out on the spot. Control activity was light during these maneuvers. Precision hover, once established, was easy to maintain. However, the steep attitude necessary to compensate for wind would make this airplane difficult to land vertically.

The quick stop went very well with no excessive attitude change necessary except in establishing a translational speed. Control motions were light to moderate.

Lateral-directional dynamics did not affect the evaluation.

CASE 153

X_u	=	-0.2	λ	=	1.5
$M_u g$	=	1.00	ω_n	=	0.82
M_q	=	-1.00	ζ	=	-0.18
M_θ	=	0			

PILOT B PR = U8 M_δ = 0.96

The configuration was rather poor probably due to high drag and a high responsiveness to gusts. The control sensitivity selected gave an abruptness in initial response but was necessary to give the control authority needed to do the task.

The ability to initiate motion in the air taxi was poor. It was difficult to stop precisely and achieve a hover at the corners. Occasionally quite large attitude changes were required. Control felt quite sensitive. Perhaps it was set too high. Response to rudder was sluggish but adequate.

The turn over a spot was poor. Airplane wandered all over and a reasonable hover was never really achieved. Initiation of a turn was adequate.

The crosswind turns were poor. Precision of hover was poor. Attitude and angular rates got to be fairly high.

The quick stop was not too good. Stopped quickly but attitude changes were excessive. Height control was not too much of a problem.

At times, it seemed that the nose was moving up and down of its own free will.

CASE 154

$X_u = -0.2$ $\lambda = 1.2$

$M_u g = 1.00$ $\omega_n = 0.93$

$M_q = -0.30$ $\zeta = -0.37$

$M_\theta = 0$

PILOT B PR = U7 $M_\delta = 0.71$

The configuration was poor. It required a sufficiently high control sensitivity to make the large amplitude pitch attitude changes required, but not so high that the initial response was too abrupt.

It was difficult to initiate motion in the air taxi. Attitude changes were high and there was a tendency to lose altitude. It was not really possible to stabilize on a preselected rate of motion. It was not really possible to stop precisely at the corners. Could not do a precision task of hovering. Ability to remain within the ground track was fair to poor. Because of the longitudinal problems, there was difficulty laterally and directionally. This resulted from involvement with longitudinal control.

The turn over a spot was very poor. Could not do it with any degree of precision. Large attitude changes were required around the turn. The airplane seemed to be quite unstable with the wind from the rear. Rudder control was a bit sluggish.

The crosswind turns could be performed but a hover could not be established very easily. There was a strong tendency to overshoot. A vertical landing would be a gamble. Control activity was excessive for hover.

In the quick-stop maneuver, the stop could be performed readily because of high drag but not with any precision. Height control suffered because of other problems in the maneuver.

Lateral-directional problems were not predominant because of the problems longitudinally. At times the pitch attitude changes seemed to cause a little PIO.

CASE 155

X_u	= -0.05	λ	= 0.8
$M_u g$	= 0.33	ω_n	= 0.64
M_q	= -0.30	ζ	= -0.38
M_θ	= 0		

PILOT A PR = A4 M_δ = 1.05

Airplane was relatively easy to fly because the pitch attitude into the wind was very low. Pitch response due to gust input was objectionably high, but the airplane could be flown with a minimum of effort.

There was not too much trouble in the air taxi around the square. The turn over a spot was flown with a minimum of effort and the crosswind turn was satisfactory.

In the quick-stop maneuver, a lot of speed was obtained and in order to stop quickly the nose was brought up too high. The simulator limits were exceeded causing a hydraulic dump. The airplane could be handled reasonably well in this maneuver by flying at a more normal speed.

PILOT C PR = U7 M_δ = 0.45

Control sensitivity was set to give smoothness to the control response. However, the system was divergent and of a frequency which lent itself to pilot-induced oscillations.

In air taxiing around the square, there was no difficulty in initiating motion in any direction, and it was quite easy to stabilize and hold a preselected rate of movement. There was no difficulty in stopping precisely at the corners or in coming to a precision hover. There were no excessive attitude changes necessary, although a slight tendency to overcontrol in the lateral axis gave some rather steep bank angles in coming to a stop on the crosswind legs. Rudder response and turn rate were low.

There was no difficulty in performing the turn over a spot, although the attitude changes would make it impractical to make very fast turns over a spot. There was a feeling that control of the airplane could be lost.

PILOT C

In performing the crosswind turns there was a definite tendency to overshoot. A pilot-induced oscillation was developed which could have resulted in the loss of the airplane. There was no difficulty establishing heading over the spot. Once established in position, hover was easy to maintain. There were no excessive attitude changes necessary to compensate for wind, and there was no difficulty maintaining position over the ground. The airplane appeared to be adequate for a vertical landing. Control activity throughout the maneuver was moderate except during the PIO when it was heavy.

In performing the quick-stop maneuver, the aircraft stopped very quickly although the simulator hit the limits once. A PIO could easily have developed. There was no difficulty in holding heading or altitude. Control motions were excessive during this maneuver.

Divergent systems like this can be flown without much difficulty as long as they are flown gingerly without any large control inputs. However, a quick stick input to avoid trees or a building could result in loss of the vehicle.

Height control requirements did not make the maneuvers more difficult. Lateral-directional or height dynamics did not affect the evaluation of the longitudinal dynamics.

[Because of an appreciable difference in pilot rating and comments in the above two summaries, the dynamic check runs made immediately prior to each flight were examined. They were found to be identical.]

CASE 157

X_u	$= -0.05$	λ	$= 2.1$
$M_u g$	$= 0.33$	ω_n	$= 0.39$
M_q	$= -2.00$	ζ	$= -0.03$
M_θ	$= 0$		

PILOT B   PR = A4½ $M_\delta = 1.07$

This was a fair configuration, but it exhibited problems in the large amplitude of pitch attitude changes. There seemed to be a slight dynamic instability. The control sensitivity may have been selected a little too high.

Motion was initiated reasonably well. This was not a high drag configuration. There was a lag in the response, but motion could be stabilized fairly well. It took a reasonable attitude change to stop precisely, but there was a strong tendency to overcontrol. Ability to stay on the ground track was not bad.

The turn over a spot was reasonably good and the spot maintained fairly well. Rudder control was adequate.

The crosswind turns were, in general, fair. It took a moderate amount of time to achieve the final position. There was some tendency to overcontrol in stopping the forward motion. The precision of hover was fair. It was adequate for a vertical landing. Control activity was moderate.

In the quick-stop maneuver, there was a strong feeling of instability as if the vehicle could get away.

There was a noticeable lateral drift. Control activity was somewhat high. It was necessary to adjust pilot input gain to prevent getting into an objectionable pitchup.

CASE 158

$X_u = -0.05$ $\lambda = 1.0$

$M_u g = 0.33$ $\omega_n = 0.58$

$M_q = -0.60$ $\zeta = -0.28$

$M_\theta = 0$

PILOT A PR = A3 $M_\delta = 0.89$

Performance in this airplane was very good. It required about a degree nose-down in pitch to hold into the wind. There was a slight response in pitch to gusts. This configuration did not seem very much different from Case 164.

PILOT C PR = A6 $M_\delta = 0.38$

This configuration was quite easy to fly, although it seemed to be divergent. It could be compensated for by pilot effort, although there was a definite possibility of a PIO developing and the loss of the airplane.

In the air taxi around the square, motion was initiated easily in each direction and the rate of movement was held steady in each direction. It was very easy to stop precisely and hover at the corners. There were no excessive attitude changes required in pitch or roll. Flight was fairly close to the ground track. Rudder control response seemed slow. The yaw rate should have been greater to match the longitudinal and lateral response.

It was easy to turn over a spot, although there was a definite tendency to overcontrol in pitch. There was no trouble in stopping on a preselected heading.

The crosswind turns worked out well. There was no trouble establishing heading but there was trouble with height control throughout the flight due to overcontrolling in pitch. Control activity was heavy; control power, adequate. There was no trouble in establishing precision hover, and once established, the attitude was adequate for a vertical landing. Control activity in the hover was moderate.

In the quick stop, the stop was made very fast, although very excessive attitude changes longitudinally caused overcontrolling. A pilot-induced oscillation almost developed.

CASE 158 (Continued)

Height control requirements made the maneuvers more difficult. Lateral-directional dynamics did not affect the evaluation. The configuration required very delicate flying and very small inputs in the longitudinal axis.

CASE 159

X_u	= -0.2	λ	= 0.5
$M_u g$	= 1.00	ω_n	= 1.975
M_q	= -3.30	ζ	= 0.760
M_θ	= -4.74		

PILOT B PR = A5 M_δ = 0.94

Control sensitivity was chosen on the basis of abruptness in initial response, and by the requirements of hover.

This was a high drag configuration and it was difficult to get moving and to stabilize on airspeed. Ability to stop precisely was fair. Attitude changes in pitch ranged from moderate to excessive. Ability to remain within the ground track was fair. Pitch control felt a little sensitive because of the abruptness in response. Rudder control was sluggish but adequate.

The turn over a spot was poor because of the large attitude changes required. It was necessary to hunt for the proper attitude when making a heading change. The ability to initiate turns and to stabilize, and the rudder control, were satisfactory.

Performance in the crosswind turns was not too bad. Precision of hover was fair to poor, but adequate for a landing. Control activity was fairly high.

There was trouble getting started for the quick stop, overcontrolling in the stop itself, and then failure to establish a reasonable hover.

Height control required a moderate amount of collective activity. There was lateral drifting when in a hover. The pitch and roll controls were quite noticeably mismatched, with the roll much smoother and having less authority.

PILOT C PR = A6 M_δ = 0.54

This configuration was difficult to fly because of the steep pitch attitude necessary to correct for wind. The control sensitivity was set to give the response necessary to produce this attitude with a minimum amount of stick movement.

In taxiing around the square, the excessive pitch attitude made it uncomfortable to go forward. In flying backwards, a very steep nose-down pitch attitude was required to stop the motion. It was necessary to fly the entire maneuver very slowly in order to stay fairly close to the ground track limits. Rudder sensitivity was low, and there was a little difficulty in holding heading.

There was a great deal of difficulty in remaining over the spot in the turn over a spot. Attitude changes were excessive and this induced large stick inputs which caused inadvertent lateral inputs. This added to the difficulty in flying this turn.

The crosswind turns worked out well. Turning into the wind, of course, stopped the movement without too large an attitude change necessary. There were no overshoot or undershoot tendencies. Control activity was moderate to heavy. Once established in a precision hover, it was easy to maintain position over a spot on the ground but the attitude of the vehicle was so steep nose-down into the wind that a vertical landing would be very difficult if not impossible to perform.

The quick-stop maneuver was performed slower than usual in order not to encounter excessive attitude changes which would go beyond the limits of the simulator. Control motions were moderate.

Height control requirements did not make the maneuvers more difficult perhaps because they were performed somewhat slowly. The large longitudinal corrections tended to cause small inadvertent inputs laterally which made following the ground track a little more difficult.

CASE 160

X_u	=	-0.2	λ	=	1.0
$M_u g$	=	1.00	ω_n	=	1.269
M_q	=	-2.80	ζ	=	0.788
M_θ	=	-3.05			

PILOT A PR = A6 M_δ = 1.28

Too much pitch attitude was required to hold into the wind and a lot of pitch-attitude change was required to move forward or backwards. The response was well-damped but then it lagged the stick.

There was difficulty in the air taxi around the square. The airplane seemed to wallow. There was a coordination problem because of the steep pitch-down attitude. Also, the motion was very sluggish.

The turn over a spot was difficult because of the sluggishness and also because the large pitch attitude changes required a great amount of coordination.

A lot of pitch-down attitude was required to get up speed for the quick stop. The stop could be easily made. There was no tendency to oscillate.

PILOT C PR = A4 M_δ = 0.50

The airplane responded well to control inputs. There was no tendency to overcontrol.

There was no trouble initiating motion in the air taxi around the square, although the attitude when translating into the wind was steeper than was comfortable. Had no trouble stopping or coming to a hover at the corners. Performance appeared to be fairly close to the ground track throughout the maneuver. Rudder response was low but there was no trouble holding heading throughout the air taxi.

In the turn over a spot, there was difficulty remaining over the desired spot due to the rather large changes in pitch attitude.

CASE 160 (Continued)

The crosswind turns worked out well although the vehicle turned slowly and this caused an undershoot of the desired spot. The vehicle could be brought to a hover immediately after rolling out of the turn without overshooting. Once established, precision hover was easy to maintain although the attitude required to counteract for wind would have made a vertical landing difficult.

The vehicle stopped very quickly in the quick-stop maneuver. There were no excessive attitude changes required except that initiating translation into the wind required a quite severe nose-low attitude. There was no trouble holding heading or altitude during the maneuver. Control motions were light to moderate.

Lateral-directional and height dynamics did not affect this evaluation.

CASE 161

X_u	=	-0.2	λ	=	6.0
$M_u g$	=	1.00	ω_n	=	0.567
M_q	=	-6.80	ζ	=	0.881
M_θ	=	-4.64			

PILOT A PR = A6 M_δ = 1.64

Airplane required an objectionable nose-down attitude to hold into the wind. The airplane was very well damped and had satisfactory pitching characteristics. The pitching due to gusts was of low amplitude and not annoying at all.

In the air taxi around the square, there was a little trouble moving forward because of the necessity to nose the vehicle down so far. Hence, there was a tendency to take a longer time than desired to get up forward speed.

Performance in the turn over a spot was very poor because of the coordination problem with nose-down into the wind and nose-up, downward. The concentration on attitude resulted in a loss of altitude.

The crosswind turn was not too much of a problem if the nose was kept down through the turn.

The quick stop was easy because the speed was low. It was very simple to stop by raising the nose to the horizon and then dropping it back down to hold position as the airplane stopped.

For normal pilot inputs the nose was right in phase with the stick which was desirable.

PILOT B PR = A5-1/2 M_δ = 1.28

This was a high-drag configuration requiring a nose-low attitude into the wind. It took quite a bit of pilot effort to accomplish the task with reasonable precision.

In the air taxi, the airplane was slow to get moving. Steady-state motion was reasonable. The gusty conditions were a problem. Heading could be stabilized. Stopping at the corners was a problem because it required very little attitude change to stop. There was a tendency to overcontrol. There was an annoying abruptness in initial response, especially for small-amplitude high-frequency inputs. Rudder control was a little sluggish.

In the turn over a spot, there were rather large-amplitude pitch-attitude changes as heading was changed. This caused trouble because it took time to establish the new attitude.

In the crosswind turns, there was a tendency to undershoot. It then took time to move the airplane to get it over the spot. The precision of hover was only fair and it required a fairly high degree of pilot effort. Hover was adequate for starting a vertical landing, however.

The quick stop was not bad, but there were height control problems. There were enough problems with the maneuver that the altitude occasionally got away.

CASE 162

X_u	$= -0.05$	λ	$= 0.65$
$M_u g$	$= 0.33$	ω_n	$= 0.723$
M_q	$= 0$	ζ	$= 0.415$
M_θ	$= -0.133$		

PILOT B PR = [illegible].6 $M_\delta = 0.71$

This was a very poor configuration. There was a tendency to overcontrol. However, a lower control sensitivity seemed insufficient to get a reasonable response from pilot inputs.

Ability to initiate motion in the air taxi was fairly good but there appeared to be a lag in response and there was a tendency to overcontrol. Ability to stop at the corners to hover was only fair, primarily because of the abruptness in initial response.

The turn over a spot was fair with some drifting and a strong tendency to overcontrol.

There was a tendency to undershoot in the crosswind turns. Precision of hover was only fair, but adequate for a vertical landing. Control activity was somewhat high with overcontrolling in pitch.

A PIO resulted from trying to make a quick stop. There was not much trouble initiating the maneuver, but once started, a pitch oscillation developed. Control motions were excessive because of the PIO. Height control was only fair because attention was directed more towards pitch attitude. There was not much of a problem holding heading.

Lateral-directional response seemed sluggish compared to pitch but it did not affect the evaluation.

Piloting technique requires that the pilot reduce his gain and make smooth, not-too-frequent inputs and accept some of the drift.

PILOT C PR = U7 M_δ = 0.30

The airplane appeared to be divergent and although it could be flown, there was always the possibility of a slight overcontrol which would result in the loss of control. Control sensitivity was set low in order to make the response fairly smooth.

In taxiing around the square, there was no trouble initiating motion in any direction and no difficulty in stabilizing and holding a preselected rate of movement. A stop could be made precisely and a hover performed at each of the corners. No excessive attitude changes were required either to start or stop translation or to compensate for wind. It was easy to stay within the ground-track limits. Rudder control was adequate, but the rate of turn that could be achieved with full rudder was unsatisfactory.

In the turn over a spot, it was not difficult to remain over the spot or to stop on a predetermined heading. Attitude control was no problem. The only problem with the maneuver was the very heavy stick activity required at all times in order to maintain control.

The crosswind turns worked out fairly well except for a definite tendency to overshoot the desired point on the ground. This was because of a wariness about putting in large inputs longitudinally. Once established in a precision hover, it was easy to maintain. There were no excessive attitudes necessary and it would be adequate for a vertical landing. Control activity in the hover was moderate to heavy. There were constant, small inputs both longitudinally and laterally.

Control was almost lost during the quick-stop maneuver. There was no difficulty in holding heading or altitude. Control motions during this maneuver were heavy.

Height control requirements did not make the maneuver appreciably more difficult. Lateral-directional or height dynamics did not affect the evaluation of the longitudinal system.

CASE 163

$X_u = -0.05$ $\lambda = 0.45$

$M_u g = 0.33$ $\omega_n = 0.901$

$M_q = 0$ $\delta = 0.222$

$M_\theta = -0.692$

PILOT A PR = A4 $M_\delta = 0.85$

The airplane response to gust input was objectionable. It seemed to be stable but it was annoying and there was a tendency to lose attitude reference for hovering into the wind.

The air taxi on the square and the turn over a spot were no trouble.

The crosswind turn was also no problem. The technique used was to start the turn with the wing down and to apply rudder into the turn. Then as the turn began to progress, the wings were leveled and the rudder used to skid the airplane around the turn.

For the quick stop, quite a bit of forward speed was developed. Stopping as quickly as possible resulted in reaching the simulator limit so a stop was made less quickly.

PILOT C PR = U8 $M_\delta = 0.42$

The airplane appeared to be divergent longitudinally. Control sensitivity was set at a nominal value. With an increased sensitivity the pilot-induced oscillations, which this system tended to generate, increased.

In taxiing around the square, there was little difficulty in initiating motion in any direction. There was some difficulty in stabilizing and holding a preselected rate of movement because of a tendency to overcontrol both longitudinally and laterally. There also was difficulty in stopping precisely at the corners and in coming to a hover. No excessive attitude changes were required and performance was very close to the ground-track limits, particularly at the corners.

There was no difficulty initiating a turn rate or in stopping on a preselected heading. Control activity was moderate to heavy throughout all maneuvers.

CASE 163 (Continued)

Once established in precision hover, there were no excessive attitude changes necessary and it was quite easy to maintain position over the ground. It was adequate for vertical landing, although a PIO close to the ground could be disastrous.

The quick stop worked out well, although there were four or five overshoots longitudinally in trying to bring the vehicle to a stop. There was difficulty maintaining altitude because of attitude changes longitudinally.

Control motions were heavy. Height control requirements did make the maneuvers more difficult. The constant longitudinal inputs made height control within the prescribed limits very difficult. Lateral-directional and height dynamics did not affect the evaluation of longitudinal dynamics. None of the three systems were well-matched in response.

[Because of the substantial difference in pilot rating for the above runs, the dynamic check cases made immediately prior to each run were examined. They were found to be identical.]

CASE 164

$X_u = -0.05$ $\lambda = 0.25$

$M_u g = 0.33$ $\omega_n = 1.286$

$M_q = 0$ $\zeta = -0.078$

$M_\theta = 1.60$

PILOT A PR = A3 $M_\delta = 0.89$

The airplane was easy to fly. The pitch response to gusts was annoying but it did not really affect the ability to fly except to upset the trim condition. A slight pitch-down attitude was needed into the wind and a slight pitch-up attitude downwind.

Performance on the square and in turning over a spot was good. The crosswind turns were not difficult. The quick stop was easy to perform. A lot of speed could be gotten up with a relatively small nose-down attitude. There was a limitation in stopping because of the simulator limitation. The nose could not be brought up far enough to stop as quickly as desired. It was very easy to control altitude because of the need for only about 1-degree pitch-down attitude into the wind.

PILOT B PR = A3 $M_\delta = 0.73$

This was a pretty fair configuration. Control sensitivity was a compromise due to the abruptness of pitch response. A higher sensitivity would have been desirable for the larger-amplitude maneuvers but the response would be abrupt and annoying.

In the air taxi, motion could be initiated reasonably well and stabilized. Could hold heading, stop at the corners, and hover. There was an almost constant pecking away at small-amplitude pitch-attitude requirements. This was quite noticeable because the initial response was quite abrupt. Lateral drift was also a problem. Rudder control was sluggish.

The turn over a spot was performed reasonably well. Attitude control was not too bad. The bank angle required with crosswind seemed to be larger than the pitch angle with headwind or tail-wind. Initiation of a turn with the rudder was all right.

CASE 164 (Continued)

The crosswind turns were reasonably good and a fairly stable hover achieved reasonably quickly. Again, lateral drift was somewhat of a problem. Precision of hover was generally quite good, but it required a fair amount of control activity. This activity was a function of the gusts. Hover was quite adequate for a vertical landing, however.

In the quick-stop maneuver, there was no particular trouble stopping but there was a tendency to get into a PIO. The pitch mode was apparently fairly high frequency. Height control required just a moderate amount of effort.

CASE 204

Y_v	$= -0.05$	λ	$= 1.0$
$L_v g$	$= -1.00$	ω_n	$= 1.05$
L_p	$= -1.95$	ζ	$= 0.48$
L_ϕ	$= -2.00$		

PILOT A PR = A 21/2 $L_\delta = 1.45$

The airplane was very easy to fly in the air taxi around the square even though the performance was not too good. This was due to pilot performance and not the airplane's characteristics. Performance could have been a lot better going around the square a second time. The airplane had good ability to stop laterally. The wings were nearly level which allowed a good reference for initiating or stopping lateral motion. The airplane had a slight tendency to be a little oscillatory. It was a little bit quick on response.

In the turn over a spot, more coordination was needed longitudinally than laterally. As the airplane got around into the wind, the nose had to be dropped to maintain the spot.

The quick-stop maneuver was very good. There were no particular problems with the gross maneuvers.

CASE 206

Y_v = -0.05 | λ = 1.0

$L_v g$ = -1.00 | ω_n = 1.03

L_p = -1.15 | ζ = 0.10

L_ϕ = -1.20

PILOT C | PR = A6 | L_δ = 1.11

In flying the air taxi around the square, there was no difficulty establishing motion or holding a preselected rate of movement. It was easy to come to a stop and hover at the corners. There were no excessive attitude changes necessary in pitch or roll. The ground track was maintained fairly closely. If it were not for a constant lateral oscillation, it would have been easy to fly.

In the turn over a spot, no large attitude changes were necessary in pitch or roll. The turn was performed close to the spot.

The crosswind turns worked out fairly well except it took time to establish a hover after rollout. This was due to oscillations. Lateral axis control activity was high. Once established, precision hover was quite easy to maintain. No excessive attitude changes were necessary to compensate for crosswind. The airplane would be adequate for a vertical landing.

In performing the quick-stop maneuver, the vehicle did not stop as quickly as desired. Even full bank limit of the simulator resulted in a large overshoot of position. Control motions were heavy. There were about four overshoots in the lateral axis.

There was no difficulty with altitude control.

The control sensitivity was set high and this may have caused the tendency to overcontrol laterally. This system could develop a PIO.

CASE 212

Y_v	= -0.05	λ	= 2.5
$L_v g$	= -1.00	ω_n	= 0.64
L_p	= -2.45	ζ	= 0
L_ϕ	= -0.28		

PILOT A PR = A3 $L_\delta = 1.49$

This was a good airplane. It required just a slight wing-down attitude into the wind. Response to gusts was negligible.

Performance going around the square was all right. There was no tendency to lose control. Everything seemed satisfactory.

PILOT C PR = A5-1/2 $L_\delta = 0.90$

The airplane was probably neutrally stable, or even unstable, at a fairly low frequency. Control sensitivity was at a level which gave a rather abrupt response which could cause a pilot-induced oscillation. The stick movements required were too large with a lower sensitivity.

There was no trouble at all with the air taxi around the square. It was easy to stabilize and hold a rate of movement, and easy to stop and hover at the corners. There were no excessive attitude changes required. The flight was very close to the ground track throughout the square. Rudder response was slow. It could have been twice as fast.

The turn over a spot was performed very close to the spot. There were no large attitude changes in pitch or roll.

The crosswind turns worked out well, but it took an excessive amount of time to come to a hover over the desired spot. Control activity was high due to constantly overcontrolling. This was because of the high control power. Precision hover was easy to establish, and once all the oscillations were damped out, it was easy to maintain. It would be adequate for vertical landing.

The quick stop developed into a PIO laterally. There were no excessive attitude changes required, and no difficulty holding heading or altitude. Control motions were excessive.

Longitudinal or height dynamics did not affect the evaluation.

CASE 218

$Y_v = -0.05$ $\lambda = 1.5$

$L_v g = -1.00$ $\omega_n = 0.82$

$L_p = -1.00$ $\zeta = -0.26$

$L_\phi = 0$

PILOT C PR = A6 $L_\delta = 0.69$

To get the desired response, the control sensitivity had to be turned up to a level that caused the system to get into oscillation in the lateral axis.

In taxiing around the square, there was constant overcontrolling laterally. There was no trouble stopping precisely at the corners and there were no excessive attitude changes necessary. Flight was fairly close to the ground track although it was an uncomfortable ride because of lateral oscillations. Rudder control was adequate for a vertical landing. Control activity, once established in the hover, was light although in all of the maneuvers it was heavy.

The vehicle stopped very quickly in the quick-stop maneuver. There were no excessive attitude changes required. Control motions were moderate. It felt as if a PIO could develop very easily laterally. The system felt unstable.

CASE 219

Y_v = -0.05		λ = 1.1	
$L_v g$ = -1.00		ω_n = 0.94	
L_p = -0.30		ζ = -0.41	
L_ϕ = 0			

PILOT A PR = U7 L_δ = 1.27

The airplane was very sensitive in roll. The frequency was high and the damping must have been low. It required constant control inputs to keep it from rolling. The gust response was undesirably high. There was constant concern that the airplane would get away. However, it did not require too much wing-down into the wind.

Performance on the square and in the turn over a spot was good, principally because not much wing-down was required. There was a constant, lateral control effort to keep the airplane from rolling excessively. It seemed to oscillate quite a bit.

The quick stop could not be performed as well as desired because of apprehension about tipping too much wing-up.

The airplane was skiddish laterally. There was constant apprehension about losing control. The selection of roll sensitivity was very critical. If it was too high, the vehicle was too oscillatory; too low, control was lost.

PILOT B PR = A5 L_δ = 0.84

Improvement in roll damping and an increase in frequency were needed. Control sensitivity was chosen to make up for sluggish response but it also created a tendency toward pilot-induced oscillations.

The air taxi around the square was fair, the overall tracing of the square was not bad, but it required work to achieve a reasonable hover. There was a tendency to PIO the aircraft in roll if maneuvers were attempted too rapidly. The airplane was quite level, which helped, and the oscillation was fairly small-amplitude so it never felt as if the airplane was getting away. But the pilot had to act as a damper in the system and this was done reasonably well.

The turn over a spot was fair but if too much time was spent longitudinally, there was trouble laterally.

CASE 219 (Continued)

The crosswind turns and precision hover were fair. A landing could probably be made but the constant roll oscillation was annoying. Control activity was moderate to heavy.

Precision of stopping in the quick-stop maneuver was poor because of a hesitation about making large amplitude inputs with this vehicle. This resulted in overshooting the spot.

CASE 225

Y_v	$= -0.2$	λ	$= 0.5$
$L_v g$	$= -0.33$	ω_n	$= 1.03$
L_p	$= -0.33$	ζ	$= 0$
L_ϕ	$= -1.00$		

PILOT A PR = A6 $L_\delta = 1.80$

The airplane required about 10 degrees wing-down to hold into the wind. It was close to having dynamically neutral stability; it had a slight tendency to be oscillatory, which was objectionable.

Performance in the air taxi around the square and the turn over a spot ranged from very good to very bad. The turn over a spot had the usual coordination problems because of the large wing-down attitude.

It was rather difficult to make good crosswind turns. They were not very smooth.

The quick stops were surprisingly good both upwind and downwind. There was no difficulty controlling the airplane.

CASE 232

Y_v	=	-0.2	λ	=	2.5
$L_v g$	=	-0.33	ω_n	=	0.47
L_p	=	-2.90	ζ	=	0.64
L_ϕ	=	-1.14			

PILOT B — PR = A4-1/2 — L_δ = 1.46

The control sensitivity was set high because the airplane was slow responding laterally. It had good damping but the initial response was abrupt. Performance overall was only fair.

Control of the ground track in the air taxi was only fair. Ability to stop at the corners and hover was fair. Hover never felt good and solid, and it required continuous inputs. This seemed to be a function of the gusts. This configuration required a fairly substantial bank angle which at times seemed excessive.

The turn over a spot was sort of sloppy. There was trouble with longitudinal control hovering downwind. Rudder control was all right.

The crosswind turns were performed rapidly without difficulty. Precision of hover was fair to poor. It required a substantial amount of control activity and concentration to hover. However, it was adequate for a vertical landing.

The quick-stop maneuver was not too bad. There was some difficulty with altitude control but that may have been due to an oversight on the pilot's part in making a wrong collective input. Generally, height control was not too bad. The longitudinal control entered into the hover. There was a looseness in control of longitudinal position.

PILOT C — PR = A6 — L_δ = 0.60

In the air taxi around the square, there was no trouble in initiating motion but it was very hard to stop precisely and come to a hover at the corners because of the excessive banking that was necessary to compensate for the crosswind. The ground track was not very accurate but perhaps within limits. Rudder response was adequately matched to the lateral system.

In the turn over a spot, the airplane did not remain very close to the spot. It got off as much as 15 or 20 feet. Attitude control was very rough about the roll axis and this caused control to be rough longitudinally also.

The crosswind turns were rather difficult to perform because of a tendency to overshoot. Once the vehicle was rolled out of the turn, it required an objectionally long time to establish a hover. Once established, precision hover was fairly easy to maintain. The bank angle required to compensate for wind seemed to be excessive to perform a vertical landing. Control activity was moderate.

Stopped quickly in the quick-stop maneuver with no excessive attitude changes required. There was no difficulty holding heading or altitude. Control motions were moderate but there was some tendency to overcontrol.

Height control was quite easy and did not make the maneuvers more difficult. Longitudinal and height dynamics did not affect the evaluation.

CASE 233

Y_v	= -0.2		λ	= 2.6
$L_v g$	= -0.33		ω_n	= 0.40
L_p	= -2.60		ζ	= 0.38
L_ϕ	= -0.39			

PILOT B PR = A5 L_δ = 1.29

The control sensitivity was set high because the airplane was a little sluggish. However, on occasion the response was abrupt. Lateral damping was good.

Performance in the air taxi was only fair. There was some difficulty in establishing motion and in stabilizing. Ability to stop precisely was fair. It took awhile to establish a steady hover and it never felt solid.

The turn over a spot was fair. Rather large attitude changes were required in both pitch and roll. Hover was wandering, not real solid. Was able to initiate turns with the rudder satisfactorily.

The crosswind turn to the right was good and a hover was achieved rapidly. The one to the left was overcontrolled and resulted in pitch problems. Precision hover was fair but would cause trouble in a vertical landing in gusty conditions. Control activity was moderate.

The airplane did not stop as fast as desired in the quick-stop maneuver; stopping when going downwind required a fairly large attitude change. Going into the wind, a smaller change was needed and hence there was a tendency to overcontrol. Height control was not good.

Except for the quick stop, height control was acceptable. Secondary dynamics did enter somewhat into the evaluation.

In general, the attitude required to offset the crosswind was too high. There was a tendency to oscillate laterally if the maneuvers were flown too tightly.

CASE 234

Y_v	= -0.2	λ	= 2.5
$L_v g$	= -0.33	ω_n	= 0.36
L_p	= -2.40	ζ	= 0.19
L_ϕ	= 0		

PILOT B   PR = A4 L_δ = 1.06

The control sensitivity was chosen a little on the low side so as not to get an abrupt initial response. This may have contributed to a sluggishness in response. However, the lateral response was fairly compatible with the longitudinal and this may have helped in performance.

Was able to initiate motion in the air taxi but there was some trouble stabilizing and a tendency to overcontrol. Fairly substantial attitude changes were required to control the rates and to stop precisely. Hovers were fair to good and the ground-track performance was fair. Control inputs seemed a little large for the resulting response.

In the turn over a spot, there was a fair amount of difficulty in anticipating bank angle. Correcting for drift required a fair amount of control input and control activity.

Crosswind turns were not bad. Precision of hover was fair to good and certainly adequate for landing. However, it required fairly hard work.

Vehicle did not stop as quickly as desired in the quick-stop maneuver. The amplitude of bank angle required for the stop was high. There were no PIO tendencies.

There were no particular problems with height control. The longitudinal response was too sluggish.

CASE 237

Y_v	=	-0.2	λ	=	0.5
L_{vg}	=	-1.00	ω_n	=	1.90
L_p	=	-1.80	ζ	=	0.40
L_ϕ	=	-3.98			

PILOT C PR = U8 L_δ = 0.66

There was difficulty maintaining the desired position over the ground in the air taxi. A great deal of difficulty was experienced stabilizing and holding a preselected rate of movement because of a constant lateral oscillation. Hovering was difficult because approximately 12 degrees of bank was necessary to compensate for the crosswind. Rudder control was sufficiently fast for compatibility with the lateral system.

In the crosswind turns, overshooting laterally caused a large pitch oscillation. There was difficulty establishing both heading and position after rollout. Control activity was very high. Once established in a hover, it was not too difficult to maintain although it would have been practically impossible to land the airplane vertically because of the bank angle.

The quick stop didn't work out well at all because of a pilot-induced oscillation with five or six overshoots.

Height control requirements did not make maneuvers more difficult. Longitudinal dynamics did not affect the evaluation.

The lateral system felt damped but of such a frequency that the pilot was constantly causing lateral oscillations.

CASE 240

Y_v	= -0.2	λ	= 1.0
$L_v g$	= -1.00	ω_n	= 1.20
L_p	= -2.80	ζ	= 0.50
L_ϕ	= -2.25		

PILOT A PR = A6 L_δ = 2.00

The air taxi around the square was not bad. It required a lot of wing-down to hold into the wind but the airplane seemed to be of low frequency. If it didn't have good damping, the pilot could easily supply it. There was no sensation of the airplane getting away on any of the maneuvers.

The turn over a spot was a real coordination exercise. It required about 12 degrees wing-down to 12 degrees wing-up as well as nose-up and nose-down going around the turn.

The crosswind turn was very easy. The airplane could be moved very quickly into the turn, and then the only concern was the nose-down attitude into the wind because the objectional lateral feature was eliminated.

The quick stop upwind was no problem because it was not possible to get much speed up. Going downwind, an excessive amount of wing-up was required.

Other than the objectional attitude required, everything was good.

CASE 249

Y_v	= -0.2	λ	= 6.0
L_{vg}	= -1.00	ω_n	= 0.48
L_p	= -6.30	ζ	= 0.52
L_ϕ	= -1.97		

PILOT A PR = A5 L_δ = 2.00

The airplane required about 10 degrees wing-down into the wind which caused coordination problems. The airplane responded well laterally in that it assumed a certain wing-down position for a lateral stick input. Could use a large roll angle in this airplane without any apprehension about losing control.

There was a great deal of trouble with ground-track performance in the air taxi. The airplane seemed to want to translate off the track and there was a coordination problem in having at least 10 degrees wing-down.

The turn over a spot was very bad because of wallowing from side to side and also because of the coordination required.

From the performance standpoint it was a relatively difficult airplane to fly. From a handling qualities standpoint, it wasn't bad in that it never had a tendency to get away.

PILOT B PR = A3-1/2 L_δ = 1.79

The response was well-damped and rather slow. The control sensitivity was adjusted to give a good responding airplane with some tendency toward small-amplitude oscillations.

Performance in the air taxi around the square was fair. It was possible to establish a lateral rate fairly well although it required moderate to large bank angles to move and also to stop. The steady-state bank angle required for the crosswind was about 10 degrees. Hover was fair to good. Rudder control was adequate.

The turn over a spot was fair. The crosswind turns were all right. Hover could be established fairly well and it was certainly adequate for a vertical landing. Control activity was moderate. There was some tendency to get into a very small-amplitude, moderately high-frequency, roll oscillation.

CASE 249 (Continued)

The quick stops required quite large attitude changes but the stops were made reasonably well and a hover achieved.

Height control was not bad throughout except for the larger amplitude lateral maneuvers such as the quick stops.

Fore-and-aft drift entered into the hover evaluation to some extent.

CASE 254

Y_v	=	-0.2	λ	=	1.2
$L_v g$	=	-1.00	ω_n	=	0.93
L_p	=	-0.30	ζ	=	-0.37
L_ϕ	=	0			

PILOT B PR = U9-1/2 L_δ = 0.97

Lost control and went into large-amplitude oscillations several times.

Performance in the air taxi was poor but it could be done. Did not stay within the ground track too well. The bank angle to offset the crosswind was about 10 degrees. Managed to reach a fairly good hover but there was almost a constant high-frequency roll oscillation and periodically a rather large-amplitude PIO.

The turn over a spot was fair to poor but again a PIO developed. It required work to achieve a hover. Rudder control was just adequate.

The crosswind turn was not too bad. The airplane was more stable when pointing into the wind and the wings were level. Precision of hover was poor although with effort a fair hover could be achieved. It may have been adequate to initiate a vertical landing but it always felt to be on the verge of a lateral PIO. Control activity was almost constant laterally. Small-amplitude, fairly high-frequency, lateral inputs were required for any maneuver.

A quick stop into the wind was performed by using a smooth, slow technique to prevent an oscillation. Going downwind, a stop was attempted a little quicker and a large-amplitude PIO resulted.

Height control did not seem to cause too much of a problem. The longitudinal dynamics did cause some problem due to sluggishness and a mismatch with the lateral system.

Roll damping was very poor. The control sensitivity was a compromise between lack of control with a low setting and a high-frequency PIO with a high setting. Piloting techniques called for doing things slowly so as not to get into a PIO.

CASE 255

Y_v	= -0.05	λ	= 0.8
$L_v g$	= -0.33	ω_n	= 0.64
L_p	= -0.30	ζ	= -0.38
L_ϕ	= 0		

PILOT C PR = U8 L_δ = 0.42

It would be very easy to get into a pilot-induced oscillation with this airplane, particularly with a higher control sensitivity.

There was difficulty in taxiing around the square due to constantly oscillating back and forth laterally. There was not too much trouble maintaining the ground track. There were no excessive attitude changes necessary since the airplane seemed to counteract with the wind without too much bank. Rudder response was good.

In the turn over a spot, control was almost lost attempting to damp out lateral oscillations.

There was difficulty in coming to a hover after the crosswind turns and there was trouble with heading due to rolling back and forth. Once established in a hover, it could be maintained but a vertical landing would be practically impossible without wiping out the landing gear.

Did not stop quickly in the quick-stop maneuver. Excessive attitude change was required and the necessary lateral control to do a normal quick stop would have caused the simulator limits to be exceeded.

Control activity was very high for all maneuvers. Height control requirements did not enter into the evaluation or make the maneuvers more difficult. Longitudinal dynamics did not affect the evaluation.

CASE 259

Y_v	= -0.2	λ	= 0.5
$L_v g$	= -1.00	ω_n	= 1.975
L_p	= -3.30	ζ	= 0.760
L_ϕ	= -4.74		

PILOT B PR = A3 L_δ = 1.77

With the control sensitivity chosen there was a slight tendency to overcontrol laterally.

In the air taxi there was a slight lag in initiating motion laterally. Could stabilize movement and stop at the corners reasonably well. The bank angle required to offset the crosswind was a little high. The airplane felt moderately snappy laterally; somewhat sluggish, longitudinally. The constant force required to support the stick off to the side was a little detrimental to control because the stick was quite heavy.

There was no real problem with the turn over a spot although there was more trouble establishing the proper pitch attitude than the bank angle. Rudder control was adequate.

In the crosswind turns, there was more problem longitudinally than laterally but it did not require too much time to achieve a good hover. Precision of hover was fairly good although there was a tendency to drift around the spot. Hover was certainly adequate for a vertical landing.

There was no particular problem with the quick stop although the lateral translation did require coordinated inputs with the collective to maintain height.

There may have been a downgrading of the configuration because the longitudinal control was somewhat sluggish.

PILOT C PR = U7 L_δ = 0.91

Airplane was very difficult to fly and prone to pilot-induced oscillations.

CASE 259 (Continued)

There was difficulty air taxiing around the square due to over-controlling laterally. There was difficulty holding a preselected rate of movement going crosswind. Rudder response was slow, but adequate for the system.

Got off the spot probably 20 feet in the turn over a spot because of oscillation in the lateral axis. The attitude changes necessary to maintain position were not excessive.

The crosswind turns worked out fairly well but there was constant stick activity. There was a tendency to undershoot slightly because it felt as if a fast turn could possibly result in loss of control with a pilot-induced oscillation. Once established in a precision hover, it was not too difficult to maintain. The bank angle was not excessive for a vertical landing but it would be difficult to land this vehicle because of the constant stick activity laterally.

Did not stop quickly in the quick-stop maneuver because full lateral input may have resulted in loss of control.

Control activity was heavy throughout all the maneuvers. Longitudinal or height dynamics did not affect the evaluation.

[Due to the substantial difference in the pilot ratings for the above cases, the dynamic check runs made immediately prior to each flight were examined. They were found to be identical.]

CASE 260

Y_v	=	-0.2	λ	=	1.0
$L_v g$	=	-1.00	ω_n	=	1.269
L_p	=	-2.80	ζ	=	0.788
L_ϕ	=	-3.05			

PILOT A PR = A4 L_δ = 1.92

The airplane needed about 5 degrees wing-down to hold the airplane into the wind. About 1 or 2 degrees would be preferable. There was no tendency to oscillate. No upsetting motion due to gusts was noticeable.

The crosswind turns and the quick stop went well. The airplane had no tendency to overshoot.

PILOT C PR = A5 L_δ = 0.96

Except for the steep banking required to correct for wind, the airplane was easy to fly.

In the air taxi around the square there was difficulty in stopping precisely at the corners and coming to a hover because of the excessive attitude required to compensate for the crosswind. The ground-track limits were exceeded several times.

The turn over a spot was performed within about 20 feet of the spot. Attitude in pitch and roll, although large, was fairly easy to maintain.

After making the crosswind turns it took an excessive amount of time to come to a desired position. Precision hover was easy to establish and maintain, although it probably would be inadequate for a vertical landing because of steep attitude required - about 10 or 12 degrees - to compensate for the wind.

The quick stop worked out well. There was no difficulty in holding heading or altitude.

Control activity was moderate throughout the maneuvers. Height control requirements did not make maneuvers more difficult. Longitudinal and height dynamics did not affect the evaluation of lateral-directional dynamics. There was no tendency to get into a pilot-induced oscillation.

CASE 261

Y_v	=	-0.2	λ	=	6.0
$L_v g$	=	-1.00	ω_n	=	0.567
L_p	=	-6.80	ζ	=	0.881
L_ϕ	=	-4.64			

PILOT A PR = A4 L_δ = 4.00

The response was well-damped and there was no concern about getting into an oscillation.

An objectionable wing-down attitude - about 8 or 10 degrees - was required to remain over a point. This hurt performance in flying the square pattern and also in the turn over a spot.

There was no problem in the crosswind turn or quick-stop maneuver.

The lateral response to stick input was a little slow even though the control sensitivity was high.

PILOT B PR = A3 L_δ = 2.00

The airplane was a little sluggish and it required an objectional bank angle to correct for wind.

The air taxi was quite good. About 10 degrees of bank angle was required into the wind. When this was not properly maintained there were deviations from the desired path over the ground. In generating side forces there was somewhat of a lag. It took a little while to displace the airplane. Could stop reasonably well.

There was no particular problem with the turn over a spot or the crosswind turns. Longitudinal control was more trouble than lateral. Precision of hover was good. There was a slow drift about the hover point but the hover was adequate for a vertical landing. Control activity was fairly small in the hover.

There was a tendency to overshoot in the quick stops. Quite a bit of bank angle was required to generate side forces and to stop the lateral motion.

There was a little problem with height control. Longitudinal dynamics were perhaps worse than the lateral.

CASE 262

Y_v	= -0.05	λ	= 0.65
$L_v g$	= -0.33	ω_n	= 0.723
L_p	= 0	ζ	= -0.415
L_ϕ	= -0.133		

PILOT B PR = 10 L_δ = 1.12

The mission cannot be flown with this airplane. Control was lost during the evaluation and a number of times it felt as if the airplane was getting away.

Lost control during the crosswind turn. There was no such thing as precision hover although at one corner of the square a steady hover was managed. The gusts disturbed the vehicle and started a PIO which tended to build up rapidly.

Longitudinally the response was sluggish. Laterally it was quite oscillatory and fairly rapidly responding. The two systems were mismatched.

PILOT C PR = U7 L_δ = 0.53

The vehicle appeared to be very lightly damped or even unstable. Control sensitivity was set to give the response necessary without large stick movements.

In the air taxi around the square there was no difficulty with the first two legs but there was difficulty maintaining the ground track on the other two. There was no trouble initiating motion in any direction and very little trouble holding the preselected rate of movement. There was trouble stopping at the corners because of the oscillation in the lateral axis. Rudder control was adequate.

Had difficulty maintaining position within 20 or 30 feet in the turn over a spot due to pilot-induced oscillations, when putting in large inputs.

The crosswind turns worked out fairly well although there was overshooting and it required an excessive amount of time to establish the vehicle over the desired spot after the turn. Once established in a precision hover, it was easy to maintain and it would be adequate for a vertical landing.

CASE 262 (Continued)

The quick stops worked out fairly well and no excessive attitude changes were required. There was no difficulty in holding heading or altitude. In trying to establish the vehicle over the desired ground spot there were about six or seven overshoots in the lateral axis.

Control activity was high throughout all the maneuvers due to the PIO tendency in the lateral axis.

CASE 263

Y_v	= -0.05	λ	= 0.45
$L_v g$	= -0.33	ω_n	= 0.901
L_p	= 0	ζ	= -0.222
L_ϕ	= -0.692		

PILOT A PR = A6 L_δ = 1.25

The airplane had a tendency to want to get away very quickly once a roll input was applied. All the roll damping had to be supplied by the pilot. The airplane would not come to an easy bank angle without the necessity for reversing the control to prevent the bank angle from running away. Constant stick movement was required laterally in an effort to keep the wings level or to move the airplane around.

It was necessary to hold the wing slightly down into the wind.

PILOT C PR = U8 L_δ = 0.40

Airplane was difficult to fly because of constant overcontrolling laterally. It should have had more control power but it then would have had an even greater tendency to develop pilot-induced oscillations.

There was difficulty air taxiing around the square, and difficulty in stabilizing and holding a preselected rate of movement because of large inputs in the lateral axis. No excessive attitude changes were necessary, although some developed. They were caused by the PIO. Had difficulty remaining within the ground track. Rudder response was a little slow.

In the turn over a spot, there was difficulty remaining over the spot. About 4 or 5 degrees of wing-down into the wind was required to compensate for the wind.

The crosswind turns almost resulted in a loss of control because of the lateral oscillations. Once established, precision hover was easy to maintain although the constant inputs would make a vertical landing very difficult. Any small disturbance could set this system off into a pilot-induced oscillation laterally.

CASE 263 (Continued)

Did not stop quickly in the quick-stop maneuver. It felt as if control would be lost if a lot more control were used.

Control activity was heavy throughout the flight. Height control requirements did not make the maneuvers more difficult.

CASE 264

Y_v = 0.05		λ = 0.25	
$L_v g$ = -0.33		ω_n = 1.286	
L_p = 0		ζ = -0.078	
L_φ = -1.60			

PILOT A PR = U7 L_δ = 1.45

The airplane appeared to be dynamically unstable laterally. It required that the pilot be constantly on the stick trying to keep the airplane from going somewhere or doing what he didn't want it to do.

Performance was not bad. The airplane could be handled. It did not require an excessive wing-dowr attitude into the wind.

PILOT B PR = 10 L_δ = 0.95

A lateral oscillation resulted no matter what control sensitivity was selected. With a higher value, a divergent oscillation occurred and the simulator hit the stops. There was an uncertainty of really retaining control and a feeling that any maneuver of consequence would result in loss of control.

THIRD SIMULATION

CASE 301

X_u	$= Y_v$	$= -0.05$		λ	$=$	0.0866
$M_u g$	$= -L_v g$	$= 0.33$		ω_n	$=$	3.00
M_q	$= L_p$	$= 0$		ζ	$=$	-0.006
M_θ	$= L_\phi$	$= -8.988$				

PILOT D PR = A5 $M_\delta = 0.729$ $L_\delta = 0.827$

This particular configuration was fairly easy to fly, but it did appear to be divergent in pitch and possibly neutrally stable in roll.

Air-taxi-around-the-square - easy to initiate motion and maintain the desired rate of motion. Stops were easy to make. Attitude changes weren't significant at all. No problem maintaining the ground-track limits. Control feel, forces, deflections, etc. were satisfactory. Good response to control inputs.

Turn-over-the-spot - attitude to control - no problem there. No comment on the turns made. Fairly easy to remain over the spot with a moderate amount of control activity.

Crosswind turns - went into the first turn rather rapidly and got into about a cycle-and-a-half oscillation in pitch, which was easily damped out. Precision hover, however, was easy to hold. It would have been adequate for a vertical landing. Very little control activity, even with this pitch oscillation.

Quick stops - no problem here and no excessive attitude changes. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features lean toward the apparent lack of damping in pitch axis. Pilot consciously had to keep it from oscillating in pitch and roll. Roll axis appeared to be neutrally damped.

Favorable features - was able to fly the mission fairly well. No special piloting techniques needed. The performance was fairly good even with the apparent lack of stability.

PILOT E PR = A5 $M_\delta = 0.605$ $L_\delta = 0.627$

Tended to be about the same in pitch and roll. Was quite wobbly and had an almost undamped oscillation. When I selected an attitude, I got an oscillation which was slow to damp out about the steady-state value; but controlling it was reasonably easy. Sensitivities - no comments.

Ability to initiate motion was poor - seemed to take a long time to get started. Once I could overcome the oscillation I could stop reasonably precisely. Attitude changes seemed about normal if I ruled out the oscillation. Could do an adequate job of remaining within the ground-track limits. Control feel - no problems. The deflections required to initiate motion were moderate. Trimming was not a problem. Response to control inputs was poor because the oscillation tended to take out the input, so I had to use a sort of complicated control input technique.

Turn-over-the-spot - no problems. Crosswind turns - nothing outstanding. Precision hover - no external disturbances noticeable. Certainly adequate to land. The quick stops were once again the area in which gross maneuvers were the most difficult to perform because of the oscillation in the pitch and roll. Had to use some complicated control inputs in order to stabilize an attitude. Secondary dynamics didn't enter the picture.

Overall Evaluation

I have outlined the objectionable features. The oscillation about the steady-state attitude was equally bothersome in pitch and roll. It was controllable and it was acceptable because I could control the oscillation easily, but I think it was unsatisfactory because of the oscillatory characteristics of the control response. I had a lot of confidence in the ability to suppress the oscillation at will, so it was a moderately objectionable deficiency, but improvement is needed.

PILOT F PR = A2-1/2 M_δ = 0.903 L_δ = 0.946

This was basically a well-behaved, smooth-flying control system. However, it was characterized with what appeared to be a little bit of instability about the trim point. When hovering there was constant inadvertent movement of relatively minor magnitude about the trim point. It was just a little bit disconcerting and caused an additional workload on the pilot due to the lack of damping in both the pitch and roll axes. With a step input the machine would continue to oscillate about the axis with constant amplitude and constant rate. Control sensitivity was selected fairly high to give the machine a reasonable rate of response to control inputs. Lesser sensitivity resulted in too slow a vehicle reaction to control inputs, and higher made it a little too sensitive.

In the air-taxi-around-the-square, the ability to initiate motion was very good. The aircraft was slightly sluggish when starting to move across the ground, but I felt it was above average overall. Ability to stabilize and hold preselected rates of movement was very good. Ability to stop precisely and come to a hover at the corners I thought was a little bit better than average. Excessive attitude changes were not required in order to initiate or stop motion. Ability to remain within ground-track limits I thought was also above average.

CASE 301 (Continued)

Control feel - basic control feel was good. Once I got used to the oscillation and lack of damping to control inputs, I got quite used to damping it out myself. Forces were normal, deflections were not extreme, and trimmability was good. Responses to control inputs I thought were slightly slow but not enough to be degrading. Sensitivity was good. Ability to hold heading was good. In the turns-over-the-spot, the ability to remain over the spot was good but a fair amount of pilot attention was needed to damp out the pitch and roll so as not to move away from the spot. It was within reasonable pilot capability. Ability to initiate turns, stabilize, and hold preselected turn rates and stop on preselected headings was good. In the turns into the wind, the times to accomplish the maneuvers were nominal. There were minimum overshoot and undershoot tendencies. Ability to establish heading and position over the spot I think was quite good. Control activity was normal for this type of maneuver and the adequacy of control power was good. Precision hover was easy to establish and maintain except for monitoring the wind effects. I'd say the aircraft control system was moderately wind sensitive. Wind gusts introduced slight attitude changes which the pilot had to correct with control movements and then also had to damp out those control movements with stick application. It was very adequate for vertical landing.

Control activity was not noticeable to maintain the precision hover. Quick stops seemed to be accomplished as fast as a pilot desired. Excessive attitude changes were not required. Ability to hold a heading and altitude was good. Control motions required were not excessive. Directional and height dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable feature was the lack of damping to control inputs in the lateral and pitch axes. I thought the overall smoothness of the system was outstanding; it was quite maneuverable and gave the pilot confidence in being able to make the aircraft maneuver and perform as he desired. No special piloting techniques were required except to recognize the lack of damping and whatever special technique might be required to compensate for that, but I felt that my reaction came quite naturally.

CASE 302

X_u	$= Y_v$	$= -0.05$		λ	$= 0.087$
$M_u g$	$= -L_v g$	$= 0.33$		ω_n	$= 3.012$
M_q	$= L_p$	$= -1.242$		ζ	$= 0.200$
M_θ	$= L_\phi$	$= -9.125$			

PILOT D   PR = A2 $M_\delta = 0.545$ $L_\delta = 0.705$

This particular configuration was very stable and easy to fly. The prescribed patterns were easy to fly and maintain. The control sensitivity selected seems to be the best to give harmony between the controls and the response desired.

Air-taxi-around-the-square - it was easy to initiate motion and stabilize the preselected rate of movement desired, and easy to come precisely to a stop at the corners. No excessive attitude changes were required. Attitude changes - pitch was a little bit more noticeable than roll. No problem maintaining the ground track. Control feel forces, deflections and trim - nothing unusual noted. The deflection required for desired response was satisfactory. No problem holding heading.

Turn-over-the-spot - no particular difficulty in remaining over the spot. Attitude control - more pitch adjustments required than roll to maintain position. Initiating turn - no comment. It was easy to stabilize on a preselected turn rate.

Crosswind turns - minimal turn required - easy to make them. There was no tendency to overshoot, and precision hovers were quite easy. Vehicle was very stable.

Quick stops were no problem. Easy to make them and come to a stop quickly. No excessive attitude changes were noted on the forward quick stop into the wind or sideways with the wind and into the wind. Control motions were considered satisfactory. No comments on the secondary dynamics.

Overall Evaluation

The only objectionable features were that (1) the control inputs into the vehicle seemed a little bumpy or jerky, and (2) there was possibly a little too much pitch-attitude adjustment when trying to maintain position over the point when doing the 90-degree turns. Favorable features - extremely stable, pleasant to fly. No special piloting techniques.

CASE 302 (Continued)

PILOT E PR = A4-1/2 M_δ = 0.503 L_δ = 0.768

I was unhappy about a little bobble that appeared in pitch from two sources. Heading into wind there was a constant upset of attitude, a very small oscillation which was annoying. Another annoyance was that any selected attitude with a stick input always had a little bit of bobble on the steady state. The attitude changes to effect a translation seemed to be excessive in pitch. Lateral case indicated the same problem in selecting an attitude, but not as much as with the pitch. As far as the turbulence was concerned, I didn't seem to notice any effects on the lateral. Air-taxi-around-the-square - I didn't like the attitude required to initiate a motion, and the little bobble on top of it didn't help. So the thing was generally sluggish moving forward in pitch. It wasn't too difficult stopping at the corners because I never did get going fast. Attitude changes seemed to be too large in pitch to generate the required motions. Should have been able to do a reasonable job on the ground track.

The control feel did bother me a little bit. I seemed to be fighting the forces in generating the required attitudes, both in pitch and roll. I didn't like that much. Sensitivities - maybe I could have used a little more in pitch. Roll seemed adequate. Turn-over-a-spot - the effects of turbulence seemed to be of small amplitude so that it didn't really bother the turn-over-the-spot. But I'm sure I should have been able to do a better job than I did. The 90-degree crosswind turns - no particular problems that haven't been mentioned. Precision hover - a little turbulence in pitch bothered me trying to be precise in hover, but it didn't really seem to affect the position. Certainly could land it. Control activity seemed to be large amplitude but the general activity seemed to be fairly low. Quick stops - couldn't really generate the velocities required. Attitude changes required were excessive. Heading, altitude, control motions - no comment. Secondary dynamics - no comment.

Overall Evaluation

Objectional features seemed to be particularly for pitch where there was a bobble due to external disturbances, and some oscillation was noticed about the steady-state attitude selected for translation. No special piloting techniques. The annoying deficiencies were the little bobbling about the steady-state attitudes selected by a given stick input, and the velocities that resulted from a pitch attitude seemed to be less than desirable.

PILOT F PR = A2-1/2 M_δ = 1.357 L_δ = 1.306

This particular control system was very smooth flying; however, it was a somewhat slow-reacting control system. When I say smooth flying, it was easy to make rate changes at the pilot's discretion. It wasn't real smooth in terms of the cockpit ride because there were small inputs from the stick which made the vehicle change attitude fairly rapidly; however, motion over the ground was fairly far behind the aircraft attitude change. Overall I liked the handling characteristics as long as I gave it sufficient time, but there was quite a lag time between control input and vehicle response in terms of rate over the ground. Control sensitivity was high in order to give the vehicle proper control power to make the aircraft change at a reasonably fast rate.

As far as air-taxi-around-the-square was concerned, I liked the response of the vehicle although it did have this time lag between the control input and the vehicle initiation of motion. I thought the ability to stabilize and hold preselected rates of movements was very good. The rate of movement was rather slow and because of this I was able to anticipate the time lag required to stop at a predetermined spot. I think the results were quite good. Excessive attitude changes were not required. Ability to remain within the ground-track limit was very good. I liked the control force, feel, and deflection characteristics, and trimmability was good. Responses to control inputs in the lateral and pitch axes were characterized by a fairly long time-delay. Sensitivities -- I felt that the vehicle had two different sensitivities. It was sort of bouncing around on top of a ball, but the main response to the control input was smooth and predictable with the time lag that I mentioned. Ability to hold heading was good. Turns-over-a-spot and ability to remain over a spot were good.

Attitude control in pitch and roll was good as long as I anticipated the time delay in the control system. The time delay in this whole system was one in which the pilot was able to adapt quite readily and make the vehicle perform pretty much to his desires. Ability to initiate turn rates was good as was the ability to stabilize and hold preselected rates and stop on preselected headings. 90-degree crosswind turns and the time to accomplish the maneuver were normal. Undershoot and overshoot tendencies were nominal. Ability to establish heading and position over the spot turned out very well. The results were reasonable in the pilot's opinion. Control activity was not excessive and there appeared to be adequate control power considering the time delay. Ability to establish and maintain precision hover was very good. Attitude and angular rates and position were all easily maintained with very little control activity. Control for vertical landing was above average. Quick stops were accomplished at a moderate rate. Excessive attitude changes were not required and the ability to hold altitude and heading was adequate. Control motions were not excessive. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

There were only two objectionable features - both fairly minor. One was the small-amplitude, fairly high-frequency cockpit response. I don't know if it was due to gusts or what, but it seemed like balancing right on top of a ball. But the ability to make the major control inputs and the major vehicle response to control inputs were not objectionable. The other objectionable feature was the time delay or sluggishness in response to a control input. When I put the input in, the vehicle took its time in assuming an attitude change in response to the control input. However, it was predictable; and as I put in a control input, the response of the vehicle was to this pilot's liking. Favorable features were that the rates and attitudes were easily attained and the aircraft behaved in a predictable manner. No particular piloting techniques were required other than taking into account the delay between the control input and the response. The vehicle did perform in a predictable, pleasant manner.

CASE 302 (RERUN)

$X_u = Y_v = -0.05$ $\lambda = 0.087$

$M_u g = -L_v g = 0.33$ $\omega_n = 3.012$

$M_q = L_p = -1.242$ $\zeta = 0.200$

$M_\theta = L_\phi = -9.125$

PILOT D PR = A5 $M_\delta = 0.886$ $L_\delta = 1.201$

This particular configuration was quite stable; however, dynamics, both laterally and longitudinally, were lightly damped to a stick input and were oscillatory. Response was OK. In air-taxi-around-the-square, initiating forward motion was OK although there was a continuous slight oscillation in pitch because of the dynamic response of the system. Stabilized OK on the forward movement. In initiating motion sideways, here again a little oscillation in roll. Would stabilize pretty well on movements forward, backward, and sideways. Stops at the corners worked out OK and the hovers were OK. Again, there were oscillations in pitch and roll. Attitude changes were not excessive. Stayed very well within the ground-track limits.

Control deflections were very small. Responses were OK in all axes. Sensitivity seemed OK. Turn-over-the-spot worked out pretty well. Again there were oscillations in pitch and roll, more noticeably in pitch than in roll. No problem stopping on the headings or getting the turn rates desired. Crosswind turns were pretty quick; did overshoot on the first one. Control activity was not excessive. Precision hovers worked out pretty good. In order to get rid of the oscillation in pitch, it was necessary to trim the vehicle for hands-off flight. Would have been OK for a vertical landing. Quick stops worked out pretty well. Attitude changes weren't excessive. In the quick stop sideways, with the wind, the vehicle did overshoot the spot. Quite a bit of control activity there, but not excessive. Did go pretty rapidly on the sideways stop. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - oscillation in pitch and roll. Favorable features - it was easy to fly and a very stable machine. Special piloting techniques were used to trim the forces out to reduce the oscillation in pitch or roll.

CASE 303

$X_u = Y_v = -0.05$ $\qquad \lambda = 0.087$

$M_u g = -L_v g = 0.33$ $\qquad \omega_n = 3.022$

$M_q = L_p = -2.455$ $\qquad \zeta = 0.400$

$M_\theta = L_\phi = -9.231$

PILOT D $\qquad$ PR = A2-1/2 $\qquad M_\delta = 1.005$ $\qquad L_\delta = 0.763$

This configuration seemed quite stable, and the response to control inputs appeared to be well-damped.

Air-taxi-around-the-square - it took just a little more nose-down attitude than desired to initiate a forward motion. However, after a motion was started it was easy to hold at a preselected rate. Moving sideways, no problem maintaining rate and getting the movement started. Very small pitch and roll changes were required throughout the square. No problem maintaining within the ground-track limits. Control feel - no comment on the forces. Deflections were very small. No comment on trim. Vehicle appeared to have good control response.

Turn-over-the-spot - no particular problem in maintaining position over the spot. Comments on pitch and roll - here again turning into the wind seemed like it took quite a bit of nose-down pitch attitude to maintain the position. Turn rates were easy to initiate, hold, and stop on preselected headings.

Crosswind turns - the time to accomplish maneuver was satisfactory, and there were no tendencies to overshoot or undershoot. Precision hover was quite easy and very adequate for vertical landing. Control activity was very light.

Quick stops - no comment here, they were easy to do. Pitch changes were very small and roll changes were small when coming to a stop from a sideways movement. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

The only objectionable feature was that it took a little too much nose-down attitude change to initiate a forward movement. Favorable features were the real nice stability. It was a pleasant machine to fly.

CASE 303 (Continued)

PILOT E PR = A3 M_δ = 0.738 L_δ = 0.733

It was good. One objection was the amount of control deflection I had to hold for an attitude. Ended up having to hold a little more force than I'd have liked for the maneuvers. Control sensitivities - no comments. Taxi-around-the-square - the attitude required and the lag in getting going were deficiencies. Seemed to have to select a fairly large attitude with more control deflection than I would have liked to use, and then there was some delay in getting started. The velocities generated for the attitude didn't seem to be what I liked - that was in pitch. So most of my comments are about pitch. I think the same holds true for the roll. I could stop very precisely and come to a hover. It was more the control deflections required that bothered me rather than the attitude changes. The control forces that I had to hold, I didn't like. It was easy to trim. The response to control inputs was nice. There seemed to be a small burble to a step and a little bit of overshoot. Turn-over-the-spot -- no problems. Crosswind turns - no difficulties. Precision hover was not a problem. Certainly adequate to land. Longitudinal quick stop - once again the forces and control deflections to select the desired attitude were more than I would have liked, and the rate of movement for that attitude was less than I thought desirable. Secondary dynamics - no problem.

Overall Evaluation

Objectional features - I think I've outlined them. The favorable features - it was very easy to fly and had pleasant attitude control in pitch and roll. No discernible external disturbances. Just a minor problem with the control deflections required to maneuver.

PILOT F PR = A2-1/2 M_δ = 1.166 L_δ = 1.205

This was a smooth flying control system and predictable, but characterized by a slight sluggishness. Response was slow from the time I put a control movement in until I realized movement across the ground. However, most other aspects of the system were to this pilot's liking. Control sensitivity was selected to be quite high in order to give desirable characteristics to the control system; that is, to minimize the time response and increase the response of the vehicle to control inputs without becoming oversensitive on the extreme end. It was considerably higher than average.

In the air-taxi-around-the-square, I felt that the ability to initiate and stabilize movements over the ground was very good with this system, as long as I took into account the sluggish response of the aircraft to control inputs. However, the aircraft reacted precisely to control inputs, and I felt that I could stop precisely and come to a hover at the corners in a better than average manner. Excessive attitude changes were not required. Ability to remain within ground-track limits was very good. Control feel was good, forces were pleasant, deflections were moderate, and trimmability was good. Response to control input in the lateral and pitch axes was sluggish and slow. Sensitivities were adequate and ability to hold heading was good. It was easy to compensate pitch and roll for the wind effects during the turns. Ability to initiate turns, stabilize on predetermined rates, and stop on predetermined headings was good. In

the 90-degree turns into the wind the time to accomplish was normal, with very minimal overshoot or undershoot tendencies. There was a slight tendency that way because of the sluggishness in response to control inputs. Ability to maintain heading and position once over the spot was very good.

Control activity was not excessive, and control power was adequate. The precision hover was easy and required minimum pilot workload to establish and maintain; it was very good for vertical landings. Control activity was minimal for hovering activity. Quick stops were performed as quickly as I preferred. Excessive attitude changes were not required. Ability to hold heading and altitude was good. Control motions were not excessive. Directional and height dynamics did not seem to affect the evaluation of this system.

Overall Evaluation

The objectionable feature would be the slight sluggish response of the vehicle from the time the control input was made until the vehicle reacted in terms of rates of movement over the ground. The favorable features: it was smooth, predictable, and gave the pilot confidence that he could control the vehicle and make it do what he wanted even though at times it was not quite as fast and as snappy as some pilots would prefer. No special piloting techniques were required.

CASE 303 (RERUN)

X_u	= Y_v	= -0.05	λ	= 0.087
$M_u g$	= $-L_v g$	= 0.33	ω_n	= 3.022
M_q	= L_p	= -2.455	ζ	= 0.400
M_θ	= L_ϕ	= -9.231		

PILOT D   PR = A2-1/2 M_δ = 0.979 L_δ = 1.025

This was a very stable machine and quite easy to fly. Response was fairly good. It was well-damped, both in pitch and roll. In the air-taxi-around-the-square, it was easy to initiate motion and maintain selected rates in all directions. Precise hovers worked out well at the corners. Attitude changes in pitch and roll were not excessive. Stayed pretty well within the ground-track limits. Control feel was good, forces were satisfactory. Deflections also were statisfactory. Normally, only small corrections were needed. Trim was OK. Response seemed to be good in all axes; just a little jerky in pitch when an input would be entered. Turns-over-the-spot worked out very well. Quite small attitude changes were required in pitch and roll. Turn rates were satisfactory. In the crosswind turns, time was not excessive; they worked out real well and were quite fast. Did not overshoot or undershoot. Control activity wasn't a factor here; control power seemed satisfactory. The precision hover worked out real well. The vehicle stayed stabilized and hands-off stability was good. Could trim it and stay pretty well in position. Appeared very adequate for a vertical landing. Control activity was very little. Quick stops worked out real well. Attitude changes were satisfactory; no large changes were required. Control motions, here again, were quite small. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - only a slight jerky movement in pitch. Favorable features - quite stable, easy to fly.

CASE 304

$X_u = Y_v = -0.05$ $\lambda = 0.087$

$M_u g = -L_v g = 0.33$ $\omega_n = 3.038$

$M_q = L_p = -4.289$ $\zeta = 0.700$

$M_\theta = L_\phi = -9.389$

PILOT D PR = A3 $M_\delta = 0.772$ $L_\delta = 1.064$

With this particular configuration, a medium control sensitivity setting was selected.

On the air-taxi-around-the-square, it was easy to initiate motion. Holding the preselected rate of movement was easy, both forward and going sideways. It also was easy to come to stops and hover at the corners. No excessive attitude changes were required. No problem in maintaining ground track within the limits. Control feel was good; forces, no comment. The deflections were small. Response to control inputs was good. No comment on sensitivities. No difficulty in holding headings.

Turns-over-the-spot - fairly easy to remain over the spot. Pitch and roll control movements were minor. No problems on the turn rate, and no problem in coming to a stop on the preselected heading.

Crosswind turns - a short time was required. No excessive maneuvering was required. There were no overshoot or undershoot tendencies. No particular problems in coming to a precision hover over the desired point. It was adequate for a vertical landing.

Quick stops - forward and sideways - both with and against the wind - were fairly easy. No excessive attitude changes were noted. Secondary dynamics - directional and height dynamics - did not have any effect on the evaluation.

Overall Evaluation

Objectionable features - nothing outstanding. It did take a little too much nose-down attitude change for the desired forward motion of the vehicle. Favorable features were that it was a very stable machine - fairly pleasant to fly. It did require a fair amount of attention from the pilot to fly this mission. No comment on special piloting techniques.

PILOT E PR = A2-1/2 $M_\delta = 0.724$ $L_\delta = 0.895$

Pilot comments not available.

CASE 304 (Continued)

PILOT F PR = A1-1/2 M_δ = 1.776 L_δ = 1.788

Overall, this was an excellent, smooth control system. The control sensitivity was selected relatively high in order to give the aircraft a quickness of response that was suitable to this particular pilot. I think I could probably adapt to this control system with quite a variety of control sensitivities. However, most pilots would prefer to have the sensitivity in the simulator set a little higher so that the vehicle would give the impression of responding a little faster to control inputs. In air-taxi-on-the-square, the ability to initiate motion and stabilize and hold preselected rates of movement was excellent. Ability to stop precisely and come to a hover at the corners also was excellent. Excessive attitude changes were not required. Ability to remain within the ground-track limits was outstanding.

Control feel, forces, deflections, and trim were all ideal. Response to control inputs was smooth and predictable on all axes. Sensitivity as mentioned earlier had to be set relatively high compared to the average setting. Ability to hold heading also was very good. The turn-over-a-spot had minimal wind effect and was excellent in all aspects as were the 90-degree crosswind turns into the wind. Precision hover was easily established and maintained with easily-compensated-for wind effects. Adequacy for vertical landing was very good. Control activity was minimal. Quick stops were performed as fast as the pilot desired without excessive attitude changes, and the heading and altitude were easily maintained. Secondary dynamics did not affect the evaluation.

Overall Evaluation

The only objectionable feature, and it was very minor, was the somewhat slow response of the vehicle to control inputs; but it was quite minimal and was compensated for in the increased control sensitivity. Favorable features: it was smooth and predictable, minimally affected by the winds and a desirable control system. No special piloting techniques were required. It seemed to be an acceleration system, but required minimal time for the pilot to monitor outside references. The aircraft seemed quite stable. There were a very few minor points in terms of the response of the vehicle that could be improved.

CASE 304 (RERUN)

$X_u = Y_v = -0.05$ $\lambda = 0.087$

$M_u g = -L_v g = 0.33$ $\omega_n = 3.038$

$M_q = L_p = -4.289$ $\zeta = 0.700$

$M_\theta = L_\phi' = -9.389$

PILOT E PR = A3 $M_\delta = 1.078$ $L_\delta = 1.100$

In general it was quite easy to fly. Just a few minor problems. On the velocity control, it was difficult to maintain a constant velocity. Velocity tended to build up for a given attitude and the result was that it was difficult to stop precisely. Tended to overshoot the spot in both pitch and roll. In roll I seemed to get going faster than I wanted to and slid considerably by the spot on the quick stops. In the air taxi, motion was initiated easily, but it was difficult to stabilize and tended to accelerate too fast. It was difficult, particularly in roll, to stop precisely; but I could fly a precise hover at the corners once stopped.

Attitude changes - they were too excessive to stop quickly. Could remain within the ground-track limits without a problem. Tended to have to hold a little more force for the attitudes than desirable. No problem trimming. Response to controls was excellent in both axes. Sensitivities - in both pitch and roll, I perhaps could have flown with a little higher sensitivity. I don't think it would have affected my evaluation. Turn-over-the-spot - no problem with attitude control. No real difficulties. Crosswind turns - tendency to overshoot as previously mentioned. Control activity - deflections were a bit larger than optimum and with a force gradient, I ended up holding more force than I would have liked. Precision hover - no difficulties. Could be landed. Control activity was not a factor. Quick stops - using the attitudes that I normally used, I could not stop as quickly as I would have liked; therefore, excessive attitudes would be required to stop more quickly. Heading, altitude - of no concern. Control motions required - no comments. Secondary dynamics - no comments.

Overall Evaluation

The objectionable feature then was a tendency for the velocity to increase and therefore make it difficult to stabilize. This applied to both pitch and roll. And then accompanying that was a tendency to overshoot the desired stopping point. Favorable features - very nice control response in pitch and roll. Even with the deficiencies mentioned, it could be flown quite nicely and the task done quite well; especially if one compensated a bit for the tendency to overshoot.

CASE 305

$X_u = Y_v = -0.05$		$\lambda = 0.087$
$M_u g = -L_v g = 0.33$		$\omega_n = 3.053$
$M_q = L_p = -6.142$		$\zeta = 1.000$
$M_\theta = L_\phi = -9.550$		

PILOT D PR = A4 $M_\delta = 0.866$ $L_\delta = 1.320$

It was not too difficult to fly the patterns as briefed. Control sensitivity, both laterally and longitudinally, did not seem too sensitive. The vehicle flew very well with hands off the stick and it could be trimmed. It was smooth flying that way. No comment on control sensitivities. They were selected at a fairly low setting compared to the range available, probably because of the quick sensitivity or quick response of the system itself.

On the air-taxi-around-the square, it took quite a bit of nose-down attitude motion to initiate forward motion of the vehicle. It was fairly easy to stabilize the rate of movement desired and it was easy to stop on the corners. No problems were experienced going sideways, either to the left or to the right, and it was fairly easy to maintain the ground-track limits. Control forces were real light. Deflections were normally rather small and it was beneficial in flying this particular configuration to trim the airplane and use as little hand control as possible. By itself it was as stable as a rock. Response to control inputs was adequate in all axes. Sensitivity was too high in the response from an input. Headings were easy to hold. Turns-over-the-spot - fairly easy to remain over the spot. Wind inputs resulted in little overshoots and constant work on the part of the pilot. However, it was easy to stop on the headings and, with some work, to maintain the spot desired. Crosswind turns - time was minimal in turning into the wind and coming to a stop and there was very little tendency to undershoot or overshoot. Of course, this was a known wind and the pilot had done it a couple of times. There was no problem in establishing a heading and position over the spot. With a little trimming into the wind it was fairly easy to maintain the position. In a precision hover, the biggest problem was longitudinal control. If a motion started, it took quite a bit of movement of the nose to stop the motion and get back to the particular spot to hover over. Quick stops forward into the wind were no problem. Easy to stop on the point without excessive movements of the longitudinal control. Quick stops from sideways movement downwind required quite a bit of lead to stop on the points, but the lateral movements were not considered excessive. Secondary dynamics, no comment. They were both good as far as maintaining height and directional control.

Overall Evaluation

The main objectionable features on this particular configuration were (1) the quick response to a stick input and (2) possibly a little excessive longitudinal nose movement to start the machine moving. Favorable features - hands off, it was

real stable. Flying a particular mission was easy enough with just a little pilot effort in some areas. Special pilot techniques - a person flying this machine would probably start trimming more than normal, and try to keep his hand off the stick when control input was oversensitive.

PILOT E   PR = A2 $M_\delta = 0.965$ $L_\delta = 1.044$

Comment on the control sensitivities - while I was doing the task I felt that perhaps I was a little high in the sensitivities, but I don't think it bothered my evaluation in any way. In the air-taxi-around-the-square, the ability to initiate motion was about the same in either direction. Perhaps the attitude required to initiate motion could be smaller, but it really wasn't a problem. Easily stabilized and held a preselected rate of movement. Could stop precisely and come to a hover at the corners. That was excellent.

The attitude changes in pitch and roll, if I were seeking perfection, would be just a little bit less, but no real complaint. No problems with remaining or the ground track as far as I was concerned. Feel forces, deflections, trim were excellent. Response to control inputs was excellent. Ability to hold heading - no problem. Turn-over-the-spot - felt I could remain over the spot precisely as I wished. Attitude control was excellent. Ability to initiate turn rate - no problems. Ability to stabilize and hold a preselected turn rate - no problems. Ability to stop on preselected headings - was able to do so with required precision. 90-degree crosswind turns - no excessive time to accomplish the maneuver. Overshoot or undershoot tendencies - none. Ability to establish heading, positional response - good, no problems. Control activity - no prob lems. The precision hover - establishing and maintaining a precision hover was excellent. No complaints about attitude and/or rates. Position control was perfect. Certainly adequate for a vertical landing. Control activity was no problem. Quick stops - could stop as quickly as I'd have liked to. Perhaps attitude changes could be a little smaller. Ability to hold a heading and altitude - no problem. No excessive control motions required. Secondary dynamics - height and direction had no effect on the evaluation.

Overall Evaluation

Objectionable characteristics - none. Favorable features - I liked the attitude control. No special piloting techniques required. It was good and pleasant, well-behaved. Certainly controllable, acceptable, and satisfactory.

PILOT F   PR = A1 M_δ - 0.584 $L_\delta = 0.588$

The overall consideration of this particular control system was very good. Regarding the selection of the sensitivities, at the low end it produced too low of a response to the controls; when the sensitivity was greater than what I considered optimum, it resulted in too quick a response of the vehicle,in which it hit the stops on the simulator and gave a jerky ride. Therefore, I settied on a sensitivity based

CASE 305 (Continued)

on those two considerations. There was quite a band, I think, which would be considered flyable and I think it would be quite adaptable to most pilots. That is, there was quite a range of sensitivities for which most pilots would be able to adequately handle the aircraft.

Ability to initiate motion was good. I could stabilize and hold preselected rates of movement quite easily. Ability to stop precisely and come to a hover at the corners was good, as long as one anticipated somewhat the wind effects. Excessive attitude changes were not required. Occasionally, of course, due to the wind as one would expect, certain attitude changes were required to compensate for the wind effect. However, overall, I would say the attitude changes were quite small in order to accomplish the task. Ability to remain within the track limits was good except on the downwind portion of the square. I did deviate off to the right. I think it was due to trying to be a little too fast on the task and if I'd have slowed down and taken my time a little more, I think I could have been more precise in the downwind track.

Control feel, forces, deflections, and trim were all very good. Response to inputs was good. The ability to hold heading was very good. In the turn-over-the-spot, this was a very flyable system. There was no particular difficulty in remaining over the spot as long as adequate anticipation of the wind effects was realized.

Pitch and roll control was quite nominal. Ability to initiate turns was good. Ability to stabilize and hold selected turn rates was also very good. I overshot some of the headings on the 90-degree turns, but it was due more to the pilot's laxness than the ability of the system.

90-degree crosswind turns - time was very nominal in order to accomplish the maneuvers. A little tendency to overshoot or undershoot. Headings and position over the spot were easy to accomplish with minimal control activity. Precision of the hover was very good. Attitude control was good and I considered the control would be very adequate for vertical landing.

Quick stops were accomplished comfortably with rather minimum attitude changes. I do not particularly like to see steep attitudes and I prefer to take a little longer time and use less attitude in order to accomplish the given task. Therefore, I felt that the quick stops with this particular control system were very good. Ability to hold heading and altitude was also very good. I did deviate a little bit on altitude. That was probably due to coming in with some collective in order to accelerate a little quicker and then not coordinating properly at the end, at which I went down about 25 feet. But with a little practice, that matter could be accomplished quite precisely and I think quite easily.

The secondary dynamics were minimal as far as the effects. I didn't see any particularly objectionable features. This was probably one of the better control systems in this evaluation.

Overall Evaluation

Favorable features - very smooth. Ability to initiate attitude changes and rate changes was outstanding. No particular piloting techniques were required. The system was a very good one and one I'd like to see in a lot of airplanes.

CASE 305 (RERUN)

$X_u = Y_v = -0.05$ $\lambda = 0.087$

$M_u g = -L_v g = 0.33$ $\omega_n = 3.053$

$M_q = L_p = -6.142$ $\zeta = 1.000$

$M_\theta = L_\phi = -9.550$

PILOT D PR = A3 $M_\delta = 1.012$ $L_\delta = 1.052$

This particular configuration was quite easy to fly and quite stable. Did have to turn the sensitivity up some because the response seemed a little slow. In the air-taxi-around-the-square, there was no problem in initiating motion in all directions. Able to stabilize and hold rate of movements fairly well. Coming to stop and hovering at the corners worked out real well. Attitude changes were not excessive. It did seem that the vehicle was a little slow to react to an attitude change. No problem maintaining within the ground-track limits.

Control feel, forces, deflections, and so forth were satisfactory. Response was satisfactory in all axes. The vehicle was stable in response to an attitude change. Sensitivities were OK. Turns-over-the-spot worked out pretty well. Attitude control was satisfactory. Pitch and roll, and turn rates were good. Crosswind turns were quite fast. Did overshoot a little on the first one. I think this was because the vehicle was a little slow to respond to an attitude change. Control activity was OK. Precision hovers worked out real well. Was able to trim it out pretty well and hold it in position hands off. Was adequate for a vertical landing. Quick stops worked out quite well. Did overshoot going sideways with the wind and overshot also going sideways into the wind. Control motions were not excessive. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - it felt like the vehicle was a little slow to respond to an attitude change. Favorable features - it was easy to fly. Good machine for accomplishing the mission and very stable.

CASE 306

$X_u = Y_v = -0.05$ $\qquad \lambda = 0.132$

$M_u g = -L_v g = 0.33$ $\qquad \omega_n = 2.000$

$M_q = L_p = 0$ $\qquad \zeta = -0.021$

$M_\theta = L_\phi = -3.992$

PILOT D $\qquad$ PR = A5-1/2 $\qquad M_\delta = 0.908$ $\qquad L_\delta = 1.096$

In this particular configuration, response seemed very quick and both pitch and roll actually appeared to be divergent.

Air-taxi-around-the-square - no difficulty in initiating forward motion or sideways motion. Pitch attitude kept varying along the track, even though the stick position and preselected rate of speed were held fairly constant. On stopping at the corners, no difficulty was encountered. No excessive pitch or roll changes were required. Was able to stay in the ground track fairly well.

Control feel, forces, and deflections again were minimal on this particular configuration. Had the sensitivity turned up a little bit because of the apparent divergence in both pitch and roll axes, thus providing better control of the vehicle. Quick response in all axes.

Turns-over-the-spot - no particular difficulty in staying over the spot. Attitude control, pitch and roll were satisfactory. No problems in initiating the turn rate, or holding the rate, or stopping on the preselected headings.

Crosswind turn maneuver - no tendencies to undershoot or overshoot. Coming to a precision hover, it was fairly easy to hold a desired hover position over the ground with very small control movements. Vehicle did seem to kind of jerk around, though in a fairly stable hover.

Quick stops - forward, very small attitude change was required to stop going into the wind. Sideways, there weren't any problems either going with the wind or stopping into the wind. Here again, control motions were minimum. Secondary dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features were that it did appear divergent both in roll and pitch. Constant awareness of the attitude was required so that control of the vehicle would not be lost. This did not present a great problem though, in maintaining control.

Favorable features - the vehicle did have good response to control inputs. No comments on special piloting techniques.

CASE 306 (Continued)

PILOT E PR = U7 $M_{\delta} = 0.525$ $L_{\delta} = 0.485$

Didn't like it, particularly in pitch. Unattended, with a small disturbance, there were divergent oscillations both in pitch and roll. Doing the task, the pitch seemed to be the most bothersome. Air-taxi-around-the-square - motion could be initiated but there was generally an undamped oscillation in pitch about the attitude selected which was rather annoying in doing the task. The ability to stabilize and hold a preselected rate of movement in pitch was difficult. In roll it seemed to have a little bit of an oscillation but it was much easier to stabilize. One could stop fairly precisely with a rather complicated series of control inputs. The attitude changes were large, especially with the oscillations. Could fly it with concentration on the ground track all right. No problem with the control feel.

Response to the control inputs was satisfactory initially. In both cases it looked like I was getting a steady attitude for a steady stick, initially, but the oscillation would almost roll it back to cancel the input. This was particularly bothersome in pitch. Turning-over-the-spot - there was some problem with attitude as I turned but it was not serious. Crosswind turns - once again the oscillation in pitch was bothersome in coming to a stop precisely. Control activity was more than normal and tended to be a dithering motion in pitch. Precision hover was controllable but lacked precision. I believe one could land it all right, given enough time. The quick stops showed up the pitch. There was continuous oscillation in pitch as I moved forward longitudinally. It wasn't dangerous but it certainly interfered with the task. Heading, altitude - no problems. Control motions seemed to be quite complicated in pitch to hold the desired attitude. Objectionable features I have already outlined.

PILOT F PR = A3 $M_{\delta} = 0.581$ $L_{\delta} = 0.624$

This was a very pleasant flight control system, very maneuverable, and quite desirable in most respects except that it had one annoying characteristic about it. In a hover when physically holding the stick still, there was a little bit of random movement around the neutral trim point of the stick. It gave the pilot a feeling of uneasiness that the machine was going to start moving either one way or the other. When I put control motions into it and was actively maneuvering it, it was a well-behaved system. But at stabilized rates of movement or in a precision hover, it was always having just a little bit of movement. I wasn't sure of which way it was going to go. The control sensitivity was slightly high in order to give the aircraft reasonably fast, quick response and adequate control power. Anything lower than this would have resulted in a little bit too sluggish a response to control inputs.

In the air-taxi-around-the-square, I thought the ability to initiate motion was very good, as well as to basically stabilize and hold preselected rates of movement. The annoyance that I spoke about earlier really didn't change the rate much, but it did affect the pilot and gave him just a little bit of concern, perhaps needlessly. It didn't seem to affect the performance of the vehicle as much as the mental attitude of the pilot. Ability to stop precisely and come to a hover at the corners was good. Excessive attitude changes were not required. Ability to remain within ground-track limits was very good. The control forces were adequate, deflections were moderate, and the aircraft could be trimmed up. Response to control inputs about the pitch and

roll axes was proper. It was quite responsive and certainly fast enough as far as this pilot was concerned. Sensitivities were set to a moderate value also. Ability to hold heading was very good.

In the turns-over-a-spot the aircraft was moderately sensitive to wind, but with proper control anticipation I could counteract the wind effects and remain over the spot. Attitude control in order to remain over the spot was easily controlled by the pilot and required just average attitude changes to counteract the wind. Ability to initiate turn rates and to stabilize and hold preselected turn rates was good. Ability to stop on preselected headings also was good. Crosswind turns into the wind - time to accomplish the maneuver was normal. There were very little undershoot/overshoot tendencies. In fact, it was very predictable and desirable in that aspect. Ability to establish headings and position over the spot also was very good. Control activity overall was quite low and control power seemed adequate. Ability to establish and maintain a basic precision hover was very good. It was somewhat of a pilot problem in the vehicle response to the trim position of the stick. It kept wanting to move off just a little bit and the stick felt just a little bit loose around the trim point. I wasn't just sure what the combination was going to do, but to maintain and establish the basic hover it was not bad at all. It was very adequate for a vertical landing, and overall control activity was quite normal for hover maneuvers. Quick stops could be accomplished as quickly as I liked.

Excessive attitude changes were not required. I thought the ability to hold heading and altitude was very good. Control motions were not excessive.

Overall Evaluation

The objectionable feature was the peculiar feeling of the aircraft about the trim point, but it was over such a small area that once I started to do a maneuver it seemed like a very good system. It was a very responsive system and predictable. The pilot was able to feel quite confident in maneuvering the aircraft with the above exception. No special piloting techniques were required.

CASE 337

X_u	$= Y_v$	$= -0.05$	λ	$= 0.132$
$M_u g$	$= -L_v g$	$= 0.33$	ω_n	$= 2.011$
M_q	$= L_p$	$= -0.887$	ζ	$= 0.200$
M_θ	$= L_\phi$	$= -4.101$		

PILOT D PR = A4 $M_\delta = 0.310$ $L_\delta = 0.587$

With this particular configuration, it was not too difficult to fly the mission. It was acceptable. The control sensitivity was fairly low, but this was required for the response and harmony desirable for this configuration.

Air-taxi-around-the-square - it seemed as if it did require quite a bit of nose-down to initiate forward motion in this configuration and it required careful attention to maintain the preselected rate of movement. There wasn't any problem stopping at the corners and coming to a hover, either going forward or sideways or backwards. No excessive quick changes were required in the air-taxi-around-the-square. Ground track could be maintained within limits but it did require careful concentration to do it. Control feel forces felt okay. Deflections were satisfactory but it required trimming a little more than usual with this particular configuration. Response to control inputs was considered adequate. Sensitivity was okay, and there was no particular difficulty in holding heading.

Turn-over-the-spot required considerable control movements for pitch and roll after coming to a stop to maintain the particular position desired. Crosswind turns - there was no excessive time required to accomplish the task. The minimal amount of time was required to maneuver in order to perform the crosswind turn. There was just a little tendency to undershoot in one of the turns. No particular problem was encountered in establishing a heading-in position over the spot.

Control activity was moderate and control power seemed adequate. In the precision hover, it seemed like the easiest procedure to use was to trim the aircraft for the hover and try to hold this trim position with very few stick movements. It did appear adequate for a vertical landing.

Quick stops - no particular problem noted here, and excessive attitude changes were not required. There was no particular difficulty in holding heading and altitude. Control motions, again, were moderate. Directional and height dynamics had no effect on this configuration.

Overall Evaluation

Objectionable features - would like a little more stability longitudinally. Laterally it seemed satisfactory. This configuration was fairly stable and difficulty wasn't too great in performing the required mission.

CASE 307 (Continued)

Special piloting techniques - the pilot would tend to trim this configuration a little to ease his task.

PILOT E PR = A4 $M_{\delta} = 0.358$ $L_{\delta} = 0.368$

I was quite happy with this configuration with one exception. There was an annoying oscillation about the steady-state attitude selected, both in pitch and roll. It was more a distraction than an influence on the ability to do anything. No problems with the sensitivities. The air-taxi-around-the-square - initiating motion seemed to require fairly large attitudes to get going. Could only develop moderate velocities with large attitudes. Stabilizing and holding a preselected rate of movement didn't seem to be any problem, although selecting a precise attitude was not possible because of the oscillation about the steady-state attitude. It didn't seem to bother things in terms of the rate of movement. No problems stopping precisely at the corners.

Attitude changes were moderate, maybe a little excessive. No problems with the ground track. Control feel - no problems. Response to control inputs - it was quite nice. It was just the steady-state problem that was bothersome. Sensitivity - okay. No problems with heading. Turn-over-the-spot - no particular problem. Ninety-degree crosswind turns - could do the maneuver just about as well as desired. Perhaps the attitude changes when coming to a hover were a bit large; not excessive. In precision hovering no external disturbances came through. Quick stops - didn't quite get as much velocity for the attitude change as desired, but I wouldn't call the attitude changes excessive. Heading and altitude - ability to hold heading and altitude - no problems. Control motions - quite acceptable. No comments on secondary dynamics.

Overall Evaluation

Objectionable features - the small annoying oscillation about the steady-state attitude in both pitch and roll and perhaps the attitude required for a given or a desired rate of movement was too much. Favorable features - no turbulence fed through, no external disturbances. The response in terms of generating the attitudes desired was good except that it was difficult to get a steady state. No special piloting techniques required.

PILOT F PR = A2 $M_{\delta} = 0.683$ $L_{\delta} = 0.695$

This was an excellent control system to fly. I felt that I could make small corrections to control rates of movement across the ground. It was characterized by the ability to maintain a very stable hover and had relatively low sensitivity to gusts. Regarding control sensitivities, low sensitivities did not give a rapid-enough responding system; and high control sensitivity, or higher than what I selected, tended to give a little rougher ride and slight overcontrol tendencies. Of course, the high control sensitivity did quicken the vehicle response. Air-taxi-around-the-square - I thought the ability to initiate motion and maintain stabilized rates and hold preselected headings in this particular control system was excellent. Ability to stop precisely and come to a hover at the corners was very good. Attitude changes with reasonably

slow maneuvers and without really trying to rat-race the machine around, were not excessive; I'd say average for most conditions. I thought the ability to remain within ground-track limits also was very good.

Control feel and responses, forces and deflections, and the trimmability were all very good. Response to control inputs in all the axes also was very good. It was predictable and without any tendency to go too far too fast. Ability to hold heading was good. Ability to remain over a spot in a hover was very good in this control system. When I had a drift rate due to the wind, I could take my time and be quite precise with this system in killing off the drift rate and smoothly correcting back to a predetermined spot over the ground. So the attitude control was easily accomplished in this system. Certainly I had to pay attention to hovering attitude and feed small inputs in pitch and roll correction into the control system; however, they were not very high frequency and of small magnitude. Ability to initiate turn rate was good. Ability to stabilize to hold preselected turn rates and to stop on a preselected heading were very good. Ninety-degree crosswind turns or turns into the wind - it was not an overly responsive vehicle as I had the control sensitivity set. However, it was adequate for my purposes, with little tendency to undershoot or overshoot. Ability to establish a hovering heading and position over a spot during these turns was very good. Control power and activity were nominal.

Precision hover - I thought this was one of the better control systems in ability to pick the aircraft up to a hover and to maintain a precision hover over a spot. One could change attitude, angular rates, and position at his discretion without undue pilot workload. It was excellent for vertical landing. Once I had the aircraft set up the way I wanted it, there was very little control activity. Quick stops - due to the slightly lower control sensitivity, they were not as quick a maneuver as some people might like, but they were completely adequate. Attitude changes were not required and I felt I was able to hold the heading and altitude within reasonable values without undue pilot effort and with minimum control motions. There were no secondary or dynamic effects on this control system, in terms of height and directional control.

Overall Evaluation

The only objectionable feature I might mention was not objectionable to me but might be to some people. The vehicle was not as responsive as some might like in terms of quickness in responding. However, I felt that the favorable features of being able to establish an attitude and hold it in a position over the ground without undue pilot workload, certainly far outweighed the objections some people might have as far as a slight slowness in response of the vehicle. No unusual special piloting techniques were required.

CASE 308

$X_u = Y_v = -0.05$ $\lambda = 0.132$

$M_u g = -L_v g = 0.33$ $\omega_n = 2.021$

$M_q = L_p = -1.699$ $\zeta = 0.400$

$M_\theta = L_\phi = -4.209$

PILOT D PR = A4 $M_\delta = 0.528$ $L_\delta = 0.681$

No comments on the selection of control sensitivity - the adjustment used seemed to give the control feel that was desired.

Air-taxi-around-the-square - forward, it seemed hard to maintain the speed selected; and sideways, it also was difficult to maintain a preselected rate of movement. No problem in coming to hover at the corners. Laterally it took a little more control movement than desired to start a motion and to come to a halt. No problem in maintaining the ground-track limits. Stick movements weren't excessive - felt to be about right. Did not use the trim. Response to control inputs seemed a little sluggish. The vehicle seemed sluggish after a lateral input, and it banked before a movement would begin. Both sideways and forward after the vehicle's attitude had changed, it seemed a little sluggish before it started movement. No comment on sensitivities. No difficulty in holding heading.

Turns-over-the-spot - no particular difficulty remaining over the spot. Attitude control - no comment. No comment on initiating the turn rate. No problem in initiating and stabilizing the desired turn rate.

Crosswind turns - no difficulty experienced here and maneuver times were short. Didn't notice any overshoot or undershoot tendencies. Hovers over the spot were quite easy. On the precision hover, control power did seem adequate, and it felt okay for a vertical landing after the precision hover.

Quick stops - forward into the wind - very little longitudinal control movement required to come to a halt and attitude changes were minimal. Laterally, no problems noted here. No comments on the secondary dynamics - did not feel they had any effect on the evaluation.

Overall Evaluation

The objectionable features - primarily establishing and maintaining a rate of movement over the ground either forward or sideways. The vehicle seemed to be slow in responding to an attitude change. Favorable features - the vehicle was quite stable. Hands off, it flew beautifully. No special piloting techniques.

CASE 308 (Continued)

PILOT E PR = A3 $M_\delta = 0.496$ $L_\delta = 0.760$

A fair configuration with a few mildly annoying characteristics. There was a mild overshoot in selecting a pitch attitude. It was mild and noticeable but not really a big problem. There was some pitch attitude disturbance which was of small amplitude and really didn't affect the performance of the task. It was more of a nuisance value. Also, holding position in the hover tended to be a little sloppy. Control sensitivities - no comments. Air-taxi-around-the-square - ability to initiate motion was satisfactory. Stabilizing and holding a preselected rate of movement was okay. Tended to overshoot the spot somewhat. Perhaps would have liked it a little more precise in the ability to stop. Attitude changes - no complaints. Ground tracking was okay. Control feel - no problem. Response to control inputs - in pitch there was a tendency to overshoot but it damped out rather quickly. The same problem didn't seem to be apparent to me in roll. Sensitivities - no comments. Heading - no problems. Turning-over-a-spot - there seemed to be a little bit of bobble in pitch when heading into the wind, the amplitude of which was not significant. Attitude control was no problem. Turn rate was okay. Crosswind turns - once again there was some slight tendency to overshoot the spot. Didn't seem to stop as quickly as I would like to have seen it. Precision hover - some turbulence in pitch. Some disturbance in pitch and attitude. The position seemed to be a little sloppy. I was sliding around somewhat. Control activity was normal and certainly the vehicle could be landed. Quick stops - I couldn't stop as quickly as I'd have liked. The attitude changes weren't excessive. Heading, altitude, and control motions - no comment. Secondary dynamics were not important.

Overall Evaluation

Objectionable features were the slight overshoot in selecting a pitch attitude which was not noticeable in roll, and the pitch attitude disturbance due to external effects. The favorable feature was an attitude system that felt solid and stable to me. No special piloting techniques.

PILOT F PR = A2-1/2 $M_\delta = 0.850$ $L_\delta = 0.710$

This was a smooth-flying control system characterized with moderate wind sensitivity and a considerable time delay between control input and attitude response. Overall it was a reasonable and desirable control system to fly. It would have been improved with a lesser time delay, but it was capable of precision control. As far as control sensitivities were concerned, they were at a relatively high setting in order to give a feeling of control power. That is, when I put some movement into the stick, the vehicle did respond with a minimum time delay. In trying to reduce the sluggishness of the response, the vehicle tended to make the pilot select a high control sensitivity. As far as air-taxi-around-the-square, the ability to initiate motion was good as long as I took into account the time-delay factor. Ability to stabilize and hold preselected rates of movement was good. Ability to stop precisely and come to a hover was good as long as I took into account the time delay. Excessive attitude changes were not required. Ability to remain within ground-track limits,I felt was quite good.

CASE 308 (Continued)

Control feel was adequate as were the forces. The deflections were normal and trimmability was good. Response to control inputs in the lateral and pitch axes was sluggish. Control sensitivity was high, but the sensitivity of the vehicle in response to control was fairly low. Ability to hold heading was good. Turns-over-a-spot - with proper anticipation of wind effects, ability to remain over the spot was good. Attitude control in pitch and roll was average and fairly easily compensated for by the pilot as far as the wind effects were concerned. Ability to initiate turn rates was good. Ability to stabilize and hold preselected rates and predetermined headings was good. Ninety-degree turns were average. Overshoot and undershoot tendencies were not there. Ability to establish heading and position over a spot in this particular system I felt was above average. Perhaps it was just luck in my accomplishing the maneuvers, but they worked out very well. Control activity was nominal. Control power was adequate. Precision hover - once established, the vehicle would pretty well maintain the hover with less than average pilot attention to vehicle attitude. It required fairly infrequent control inputs in order to maintain a precision hover over a spot. Attitude changes and angular rates could be initiated at the pilot's discretion, but he had to compensate for wind effects. I felt that the hovering ability of the vehicle was slightly above average, and completely adequate for a vertical landing. Control activity for the hovering maneuvers was below average. Quick stops weren't snappy, but were slightly below average in terms of time required to accomplish. Excessive attitude changes were not required. The vehicle stopped quite nicely when I approached the spot. Ability to hold heading and altitude was good. Control motions were nominal. No secondary effects.

Overall Evaluation

Objectionable feature would be the time delay between control input and vehicle response. Favorable feature - it was smooth. Desired rates were able to be attained in terms of turn rates and rates of movement across the ground. Wind sensitivity was moderate - it was neither favorable nor objectionable. No special piloting techniques were required.

CASE 309

$X_u = Y_v = -0.05$ $\qquad \lambda = 0.132$

$M_u g = -L_v g = 0.33$ $\qquad \omega_n = 2.036$

$M_q = L_p = -2.933$ $\qquad \zeta = 0.700$

$M_\theta = L_\phi = -4.372$

PILOT D $\qquad$ PR = A2-1/2 $\qquad M_\delta = 0.532$ $\qquad L_\delta = 0.557$

General comments - very stable configuration, longitudinally and laterally. A medium sensitivity on the controls was selected so that - since it was very stable - there was some control over the vehicle while making inputs.

Air-taxi-around-the-square - no problem in initiating motion and maintaining a preselected rate of movement. Stops were precise at the corners and attitude changes were minimal throughout the pattern, both in pitch and roll. The ground track could be maintained pretty well. Control feel was good. No comment on the forces. The corrections were rather small. Attitude changes and attitude required were quite small.

Response to control inputs was good. No comment on sensitivity - no difficulty in holding headings.

Turn-over-the-spot - able to maintain pretty well over the spot. Here again, very small changes in attitude were required and there was no problem in initiating turn rate, holding, and stopping in preselected headings. Overshot a couple of headings.

Crosswind turns - quite easy with this particular configuration. There was no tendency to overshoot and it was quite easy to come to a precision hover over a desired position. It would have been a very adequate machine for vertical landing. Control activity was minimal in the precision hover. Very small stick movements.

Quick stops worked out very well and attitude changes were quite small. No particular problem in holding heading in altitude. Control motions - throughout most of the flight very little control motions were required. On secondary dynamics, no comments here.

Overall Evaluation

Objectionable features - nothing really outstanding here. The most favorable feature was that it was a flyable machine and pleasant to fly. No comment on special piloting techniques.

CASE 309 (Continued)

PILOT E PR = A2-1/2 M_δ = 0.563 L_δ = 0.625

General comments - the only drawback was that the attitudes required to generate motions and stop them were larger than desirable. No external disturbances. The position control in the hover was excellent. Sensitivities - a little too sensitive in pitch. I was getting slight little bumps due to small inadvertent inputs. No effect on the evaluation. Air-taxi-around-the-square - ability to initiate motion required more attitude than I would like. But generally, preselected rates of movement could be stabilized. Hovering precision was excellent.

Attitude changes to stop were large but not really all that bothersome considering the overall control characteristics. There was no apprehension in using large attitudes. Ground track could be done as well as one wanted to put the effort into it. Response to control inputs - okay. Turning-over-the-spot - no problems. Crosswind turns - no comments. Precision hover was excellent. No external disturbances. No problems with attitudes while turning. I certainly could land it. Quick stops - didn't move as fast as I would like to have seen it for the attitude changes. Fairly large attitude changes were required to stop. But one wouldn't hesitate to use them with this attitude system.

Overall Evaluation

Objectionable features - the magnitude of the attitude changes required to initiate and stop motion was more than optimum. Special piloting techniques - none. It's controllable, acceptable, satisfactory. And it's good, pleasant, well behaved. But the attitudes were a little bit large.

PILOT F PR = A2 M_δ = 0.774 L_δ = 0.817

This was a very well-behaved, pleasant system to fly. Control sensitivity was pretty much of an average value. Anything lower than a moderate setting left a little to be desired in rate of response of the vehicle to control inputs. Anything higher than an average setting on the simulator resulted in a little too sensitive response to control inputs and a little sloppiness around trim position which caused a little additional pilot workload. In the air-taxi-around-the-square, the ability to maneuver and initiate motion was good. Ability to stabilize and hold preselected rates of movement was also good. Ability to stop precisely and come to a hover at the corners was also a little better than the average control system. Excessive attitude changes were not required. Ability to remain within ground-track limits was good. I had a couple of deviations in my ground-track maneuver although I think it was due more to the pilot than to the characteristics of the control system.

Control feel, forces, deflections, and trimmability were all desirable. Response to control inputs was adequate in all axes. Sensitivities to control inputs were adequate. Ability to hold heading was good. Turns-over-a-spot - it was easy to remain over the spot with proper compensation for wind effects. Attitude control was good in both pitch and roll with no extreme attitudes required to maintain position. Turn rates were easy to establish and maintain, and I could stop reasonably well on a preselected heading. In the 90-degree turns into the wind, the time to accomplish the maneuver was quite nominal.

There were no undershoot or overshoot tendencies and I felt the ability to establish position and heading over the spot was above average. Control activity was not excessive. Control power seemed very adequate. Precision hover was easily established and maintained. It was completely adequate for vertical landing control. Control activity was minimal for hovering maneuvers. Quick stops were performed as quickly as desired. No excessive attitude changes were required. I think if a person wanted to attain steeper attitudes, he could do them quite reasonably well and precisely without the aircraft having a tendency to get away from him. Ability to hold altitude and heading during quick-stop maneuvers was good. No excessive control motions were required. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

I didn't see any objectionable features worth noting. Favorable features - it was a responsive, predictable, and easy-to-fly control system. No special piloting techniques were required.

CASE 310

$X_u = Y_v = -0.05$ $\lambda = 0.132$

$M_u g = -L_v g = 0.33$ $\omega_n = 2.051$

$M_q = L_p = -4.185$ $\zeta = 1.000$

$M_\theta = L_\phi = -4.537$

PILOT D PR = A2 $M_\delta = 0.681$ $L_\delta = 0.585$

Pilot comments not available.

PILOT E PR = A3 $M_\delta = 0.893$ $L_\delta = 0.889$

I didn't like the way that it was slow in starting to move and it was hard to stop both in pitch and roll. I had to select a pretty large attitude and then it was a while getting moving. Once it got moving, it seemed to consistently slide past the spot where I wanted to stop. Otherwise, it was quite pleasant. Air-taxi-around-the-square - ability to initiate motion, I just commented on that. Could stabilize and hold a pre-selected rate of movement. With a little anticipation I could stop precisely and come to a hover at corners. Attitude changes required - I wouldn't say that they were excessive, but they were a little more than I would have liked. I could remain within the ground-track limits easily.

The control deflections were a little large. It was easily trimmed. The response to control in pitch and roll was no problem. Sensitivities were OK. Ability to hold a heading - no problem. Turning-over-the-spot - no particular problems. Crosswind turns took a little more than normal time to accomplish, since I didn't move very fast with a given attitude. No tendency to undershoot if one realized the limitations. Precision hover - small problem with attitude and the position was not as good as it could be. Certainly adequate to land and the control activity was normal. Quick stops - same complaint as before - hard getting started and hard to stop. I wasn't afraid to use the required attitudes to stop. I used large attitudes but I was confident in using them.

Overall Evaluation

The objectionable feature was that the vehicle was slow in getting started for given attitude change and hard to stop. No special piloting techniques.

PILOT F PR = A1-1/2 $M_\delta = 0.716$ $L_\delta = 0.759$

This was a very smooth, predictable, solid-feeling control system. It was very much to this pilot's liking. Control sensitivity was at a minimum high setting, just slightly above the average setting that I have been using here in order to give the

aircraft a little bit quicker response to control inputs. A lot of pilots probably would have selected an even higher setting than I did in order to give even a greater response, but I liked the solid feeling that this particular setting gave me. As far as the air-taxi-around-the-square, I thought the ability to initiate motion in each direction was very good, actually better than average. The ability to stabilize and hold preselected rates of movement was excellent. Ability to stop precisely and come to a hover at the corners was also excellent. Excessive attitude changes were not required in pitch and roll to compensate for wind changes. Ability to remain within the ground-track limits, I thought, was above average.

Control feel, forces, deflections, and trim, all were above average in this pilot's estimation. Response to control inputs about the pitch and roll axes felt solid. Some people probably would prefer a little quicker responding vehicle than this, but it was certainly very acceptable the way it was. As far as sensitivity to gusts in the tracking maneuver, the aircraft control system was very reasonable. Ability to hold heading was also good. In the turns-over-the-spot, I thought the ability to remain over the spot was above average. Attitude control of pitch and roll was average. It was a little sensitive and it certainly did require some attitude changes to compensate for wind effects, but it certainly was normal for the hovering vehicle. Ability to initiate turn rates was good, as well as to stabilize and hold preselected turn rates and to stop on preselected headings.

In the 90-degree turns into the wind, the time to accomplish the maneuver was normal. There were no overshoot or undershoot tendencies. Ability to establish headings and positions over the spot, I thought, was above average with this system. Control activity was nominal and control power was adequate. I thought it was very easy to establish and maintain a precision hover. Attitude and angular rates were easily controlled and maintained with very minimal pilot attention to attitude and control inputs. It was excellent for vertical landing. Control activity was very minimal for hovering maneuvers. Quick stops were performed as quickly as I preferred, with the particular control sensitivity that I had selected. I couldn't generate a much faster rate across the ground than what I had. It was probably fast for my purposes. Some people might prefer to see a little bit more ability or more capability for speed across the square. Excessive attitude changes were not required. Ability to hold a heading and altitude, I thought, was outstanding with this system. Control motions were not excessive in any manner. Directional and height dynamics did not seem to affect the evaluation.

Overall Evaluation

No serious objectionable features. Some people might want to see a little faster reacting control system, but I think that small criticism was certainly overshadowed by the solid feeling and the predictable nature in which the vehicle responded to control inputs and the smoothness with which the vehicle responded. No special piloting techniques were required.

CASE 311

X_u	$= Y_v$	$= -0.05$	λ	$= 0.374$
$M_u g$	$= -L_v g$	$= 0.33$	ω_n	$= 1.000$
M_q	$= L_p$	$= 0$	ζ	$= -0.162$
M_θ	$= L_\phi$	$= -0.878$		

PILOT D PR = U7 $M_\delta = 0.728$ $L_\delta = 0.522$

This configuration overall was very difficult to fly and control. It was unstable both laterally and longitudinally. In the selection of control sensitivities, a good harmony between the lateral and longitudinal control was sought with which it would be easiest to fly this particular configuration.

In the air-taxi-around-the-square, longitudinal movement was hard to control on this particular vehicle. In other words, a slight input would overshoot. It was hard to achieve the proper movement of the machine, and after moving forward it was difficult to hold the particular rate of movement. There wasn't any particular problem in coming to a stop. At the corners, however, it did take excessive longitudinal movement and lateral movement. Excessive attitude changes occurred. They were not necessarily required, but they did occur. It was difficult to maintain the ground-track limits because of the lack of stability of this particular configuration.

Control feel and forces were OK. Deflections were excessive. The trim was not used on this particular run.

Response, both on the lateral and longitudinal controls, was fast. No particular difficulty in holding a heading.

Turn-over-the-spot - here again, it was difficult to remain over the spot. Pitch and roll control was difficult, especially after stopping for a particular turn. It wasn't hard to hold the turn at a preselected turn rate. After coming to a stop, though, the lateral and longitudinal axes were excited and it took quite a bit of control movement to damp out the movement.

Crosswind turns - the time to accomplish this movement wasn't particularly excessive; rather, there was a tendency here to undershoot a little bit because of the lack of stability of the machine. In hovering over the spot, there was considerable difficulty into the wind and it took excessive longitudinal movement of the aircraft to maintain the position, especially if the vehicle started going backwards a little bit. There was a lot of control activity at that point. In the precision hover there was a lot of control activity and it was difficult to maintain position.

Quick stops - they were approached cautiously because of the lack of stability of the system configuration. There wasn't any particular problem in coming to a stop. There was a slight PIO tendency which could be damped out by the pilot forward and sideways. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features were the lack of stability, both laterally and longitudinally; the extreme difficulty in flying the mission; and the overshoot tendencies and increased pilot effort to fly this configuration. Favorable features - none in this configuration. Special piloting techniques were to try to avoid any excessive lateral and longitudinal movements - in other words, to go around real slow and avoid any excessive lateral movement to induced PIO. The machine was flyable, but unacceptable. There were major deficiencies which required improvement.

PILOT E PR = U7-1/2 M_δ = 0.201 L_δ = 0.233

Considerable difficulty was experienced setting the control sensitivities. I felt that I wanted to reduce the sensitivities perhaps even more than I was able, and at one stage I actually reduced them to zero. Lost control a couple of times while playing with the sensitivity pot. I guess the general comments on the model would be that it was very oscillatory and I felt that I was just barely in control of it most of the time.

The air-taxi-around-the-square - there seemed to be a conflict in my mind about how much attitude was required to initiate motion. Once initiated, I didn't seem to have any problems sustaining a motion and, therefore, at times I felt I didn't have to use much attitude. But at other times I was using what I thought were excessive attitudes. The quick stops left me confused as to just what the situation was. Perhaps the oscillations clouded my impression. So, it didn't seem difficult to initiate motion and it was difficult to stabilize and hold a prescribed rate of motion because of the oscillation. I was marginally able to stop where I wanted to at the corners.

The attitude change - once again, the oscillations were of such a nature that I wasn't really able to judge the attitudes required to initiate motions versus the oscillation. Felt that I could remain within the track limits with a good deal of concentration. No adverse comments on the control system. Response to control inputs seemed to be excessive. Was constantly overcontrolling and triggering off this oscillation. Sensitivities - never really was happy with them. No problems with the heading. Turn-over-the-spot - considerable difficulty doing any sort of precision turn over the spot. Generally, the attitude control, both pitch and roll, was marginal. Had a good deal of difficulty every time I changed heading in controlling the attitude. No problem with turn rate. Once settled down, I could hold a preselected heading all right. Ninety-degree crosswind turns - there was excessive time to accomplish the maneuver. Never felt that I accomplished it with any satisfaction. No other comments on the crosswind turns. Precision hover - not precise. I think I'd have a little bit of difficulty in landing this machine with the oscillations and tendency to overcontrol. So, control activity was too much.

Quick stops - I really hesitated to do a true quick stop because I didn't really feel that I was in control of the vehicle. I'm not sure that excessive attitude changes were required but they sometimes happened. Heading and altitude - no problem. Control motions - too much. Secondary dynamics didn't enter into the picture.

CASE 311 (Continued)

Overall Evaluation

Objectionable features - mainly the oscillation and a sort of incipient loss-of-control feeling. Almost felt as if I was inducing some of the oscillations or sustaining them. Favorable features - I couldn't find many. Special piloting techniques - really felt that I was flying with extreme care and a good deal of compensation. It was just marginally controllable to me. Certainly it was unacceptable. And I felt that the concentration level was just too high.

PILOT F   PR = A2 $M_\delta = 0.417$ $L_\delta = 0.463$

The control system in general was a good one to fly. I think it became better as I obtained more experience with the control system. It was difficult for me to initially obtain an optimum setting of control sensitivities. At first I tried the sensitivities very low and it gave a nice sense of control to the pilot, in that he could initiate and control small rates quite precisely. However, it was a little bit too sluggish in order to accomplish some of the maneuvers that were desirable. Going to a higher sensitivity, it became a little more difficult to establish slow, precise rates or hover over a spot without quite a bit of very small stick activity. Therefore, I had to select something of a compromise in which it was perhaps a little more sensitive than I wanted. But it was necessary in order to give a responsiveness of the overall system so that I could initiate maneuvers in a crisp manner. In other words, quick without being too grandmotherish in the approach maneuver.

The air-taxi-around-the-square was probably affected more by the pilot's laxness than by the control system, and at one point I think the altitude went off. Going laterally I drifted forward or aft. Primarily, it depended on the pilot's ability to pick up slight changes in direction with peripheral vision while maintaining attitude looking out front. As far as holding the heading, it was not much of a problem; however, the rate of movement did have some difficulties associated with it. I did have difficulty in stopping precisely and coming to a hover precisely at the corners. This was particularly noticeable in trying to stop after the backward leg. I think it was because I wanted to have that reference line out pretty much in front and, therefore, I overshot in the rearward direction. This was a problem I noted in all evaluations so far -- just not stopping the maneuver soon enough, so that I overshot in the rearward direction.

The attitude changes were quite mild in order to attain the results desired. Ability to remain within track limits, again, was affected more by the pilot's limitations than by those of the control system. I felt the control feel, forces, deflections, etc., and the trimmability of the system were good. Ability to hold heading also was good. Turning-over-a-spot - again, I thought the control system was pretty good and just the pilot's slowness in anticipating wind effects caused drift. Sometimes the roll and pitch corrections caused a little bit of a pilot workload, but I think, with a little bit of experience and anticipation of the wind effects, that he could learn to fly this particular control system quite well and quite precisely. The stabilization of preselected turn rates was good. Again, positioning over the ground was not the best. The ability to stop on a preselected heading was good. I thought the 90-degree crosswind turns went reasonably well. On any of these maneuvers, it took timing and practice to really accelerate and then make a turn and stop over the predetermined spot. For the initial attempt overall, I think these maneuvers were accomplished fairly well with

CASE 311 (Continued)

very minor overshoot and undershoot tendencies. During the turn and when rolling out into the hover condition, the ability to hold the heading and relative attitude was good. I just had to anticipate the wind effects in order to keep from moving off.

Control for vertical landing I considered to be very good. Control activity was quite minor for a hovering-type landing. Quick stops - attitude changes were quite nominal and there were no problems stopping into the wind; the same with the downwind quick stop. Ability to hold heading and altitude was good. The quick stop worked out quite well in altitude. Again, this was a matter of luck in picking out how much to compensate with the collective and attitude changes. Of course, the steeper one makes the nose-down movement into the wind, the more collective he's going to have to add at the beginning of the maneuver and the more he is going to have to take off at the end in order to hold altitude within reason. Therefore, altitude control is strictly a function of the quickness with which one performs the maneuver. The control motions, in order to maintain control of the aircraft, were quite nominal. Secondary dynamics were not a factor.

Overall Evaluation

Objectionable feature was probably trying to come up with that optimum control sensitivity setting to make the aircraft maneuver fast enough without having a tendency to overcontrol with the cyclic stick. Favorable features - lower control sensitivities made a fairly predictable, smooth-flying control system. Special piloting techniques - in order to get quickness in the response of the aircraft, I had to go to a little bit more control sensitivity than I probably would have asked for ideally. However, with just a short amount of experience, I think I could learn to fly this particular control system very precisely.

CASE 311 (RERUN)

$X_u = Y_v = -0.05$ $\qquad \lambda = 0.374$

$M_u g = -L_v g = 0.33$ $\qquad \omega_n = 1.000$

$M_q = L_p = 0$ $\qquad \zeta = -0.162$

$M_\theta = L_\phi = -0.878$

PILOT F $\qquad$ PR = A2-1/2 $\qquad M_\delta = 0.628$ $\qquad L_\delta = 0.646$

This was a pretty maneuverable flight control system which was also predictable. It also was characterized by a slight amount of random movement about a trim point. For example, during a precision hover when trimmed up, I had random movement which required pilot attention to maintain a precision hover or a rate of movement; but it had adequate performance and was maneuverable enough to make it a very acceptable system. Control sensitivity was medium high in order to give the aircraft pleasant quickness in response to control inputs and yet not be overly sensitive to small corrective inputs into the stick.

Tracking-around-the-square - I thought the ability to initiate motion in each direction was quite good. Preselected rates of movement could be modified pretty much at the pilot's discretion. It was degraded somewhat by the random movements that the aircraft demonstrated to wind gusts about the trim position. As for the ability to stop precisely and come to a hover at the corners, there was a slight tendency to overshoot or overcontrol while establishing the momentary hover; but overall, it was quite good. Excessive attitude changes were not required in order to accomplish the maneuver. Ability to remain within ground-track limits seemed to be quite good.

Control feel - after just flying a no-force system, the forces seemed a little heavy. After a short time the pilot adapted to them fairly well, and the forces and deflections and trimmability were all reasonable. Response to control input was pleasantly fast and at a good rate to pitch and roll inputs. It was not oversensitive to stick movements and control inputs. Ability to hold the heading was also good. In the turns-over-the-spot, the ability to remain over the spot was really quite good, as long as the pilot anticipated the wind effects. Very nominal attitude changes were required to compensate for the wind. Ability to initiate the turn rate, to stabilize and hold preselected headings was quite good. Ninety-degree crosswind turns into the wind could be accomplished at an acceptable speed. There was a little overshoot or undershoot tendency but the ability to establish a heading and position over the spot was quite good. Once established in the hover, I did have to pay attention to small random movements about the trim position, but they were not excessive.

Control power was very adequate, and control activity for that type of maneuver seemed very normal. Ability to basically establish a precision hover was good, but it did take a little extra pilot attention and pilot input to maintain a desired position due to random movements about the trim point. It was very adequate for a vertical landing. Control activity was not excessive. Quick stops were performed as quickly as I preferred. Excessive changes were not required. I could attain a reasonably

steep attitude and control it quite easily and, at my discretion. I could stop the maneuver a little more quickly than normal. Ability to hold a heading and altitude was good. Control motions were not excessive during the maneuver. I don't believe the directional and height dynamics affected the evaluation.

Overall Evaluation

The random movement about the trim position required a little bit of extra attention, but did not introduce a serious additional workload on the pilot. Favorable features - it was responsive to the pilot inputs at a predictable rate. The pilot felt that he could pretty well maneuver the aircraft at his desire and discretion. Control power was good. Attitude changes were quite reasonable, but then there was a little bit of a delay before the aircraft started moving and attained a reasonable rate of the control position; but it was not really that bad. No special piloting techniques were required.

CASE 312

$X_u = Y_v$	$= -0.05$	λ	$= 0.374$
$M_u g = -L_v g$	$= 0.33$	ω_n	$= 1.018$
$M_q = L_p$	$= -0.731$	ζ	$= 0.200$
$M_\theta = L_\phi$	$= -1.154$		

PILOT D   PR = A5 $M_\delta = 1.121$ $L_\delta = 1.104$

This particular configuration appeared to be unstable in roll. Pitch seemed to be stable. Sensitivity had to be turned up to achieve a better response for this system.

Air-taxi-around-the-square - forward motion was kind of jerky. It was fairly difficult to maintain a preselected speed forward. Sideways the speed also varied. Stops at the corners were satisfactory. Attitude changes were not excessive. Ground track could be maintained fairly well. Control feel forces were satisfactory. Deflections were small. Response may have been a little slow in roll and pitch.

Turns-over-the-spot - remained over the spot pretty well. Rates and so forth were satisfactory. Also stopping on the heading.

Crosswind turns - very short amount of time was required. Didn't undershoot or overshoot, and maintaining position over the spot was satisfactory in the precision hover. A vertical landing could be accomplished okay in this machine.

Quick stops - no comments here. No problem coming to a stop forward or sideways. Secondary dynamics, directional and height, didn't affect the evaluation.

Overall Evaluation

Objectionable features were that the machine wasn't very stable and required constant attention and continuous control inputs to maintain control and make it do what was desired.

Favorable features - nothing really outstanding there. No comment on special piloting techniques.

PILOT E   PR = A4 $M_\delta = 0.586$ $L_\delta = 0.593$

In general, it was very responsive to controls, very positive. Maneuvering was quite pleasant and easy to accomplish. Did have some external disturbances which, with a little inattention, could trigger off in both pitch and roll moderately rapid, divergent oscillation, which really detracted from the overall characteristics. But the controls were such that this kind of oscillation could be easily controlled. For the air-taxi-around-the-square, I seemed to get a modest, steady velocity for a given pitch attitude; whereas in roll, the velocity didn't seem to increase very rapidly. I could stop precisely enough at the corners, and I wouldn't say the attitude changes

required were excessive. I wasn't worried about using the attitudes required. Could fly the ground track quite accurately.

The control deflections - one could use rapid, large deflections with confidence. The forces and feel didn't enter into the picture. Trim - one wouldn't remain very long in trim if one didn't pay attention, because external disturbances would trigger off an instability. Response to control inputs was excellent in both axes. I felt that I had complete control. Turns-over-the-spot - no real problem. Ninety-degree crosswind turns - no comments. Precision hover was good, adequate for landing. Control activity - no particular comment. In the longitudinal quick stop, the velocity generated was modest. Used fairly large attitudes to stop, but with confidence. Laterally, the velocity seemed to increase a little more rapidly than desired, but there was no problem stopping the vehicle. Heading, altitude - no problems. Control motions required large, rapid inputs to change the attitudes, but it was not a problem to do so. Secondary dynamics - not a problem.

Overall Evaluation

It was controllable and in spite of the oscillatory nature of the pitch and roll for mild disturbances, it was acceptable. But I have to say it is unsatisfactory because of a tendency to go unstable if left unattended. Because of the nature of the control response, I will class this an an annoying deficiency.

PILOT F PR = A3 $M_\delta = 0.457$ $L_\delta = 0.501$

With a relatively low sensitivity, this became a fairly pleasant system to fly. It was characterized by fairly slow aircraft response to pilot inputs. However, the rates and attitudes and the entire response of the vehicle were quite predictable and made it quite a pleasant flying system as long as one took into consideration the time delay and the sluggishness basic to this system with a low sensitivity. Higher sensitivities, of course, gave faster response to control inputs. However, while they did not lead exactly to PIO tendencies, they made the system a little too fast reacting and they degraded the system precision as far as this pilot was concerned.

As far as the air-taxi-around-the-square was concerned, ability to initiate motion was average in each direction except that I did have some difficulty starting to back up, but I felt that I still had reasonably good control of the aircraft. I did line up on the wrong line and had to stop and move back on over. I felt that these small corrections were fairly easy to accomplish and therefore the ability to initiate and maintain motion was rated pretty good with this system. Ability to stop precisely and come to a hover at the corners was tied into the pilot's accuracy of guessing just when to lead the movement with control inputs in order to stop exactly on the spot. Within a very short time I think a pilot could adapt well to the system and enable the precision stops to be accomplished quite well. Once established, the hover was easy to establish and maintain at the corners. Excessive attitude changes were not required to accomplish the tracking task. Ability to remain within ground-track limits was fair. It wasn't outstanding and it wasn't too much below average either.

Control feel - somewhat the feel of a large aircraft due to the rather sluggish response to control inputs; however, the forces were reasonable. Deflections were not excessive. It was not real easy to trim up, but not too bad. Response to control inputs in pitch and roll was characterized by a little bit of sluggishness due to the relatively low control sensitivity selection. Sensitivities of the aircraft were average. Ability to hold heading was good. Turns-over-a-spot - ability to remain over a spot was good. Attitude control in pitch and roll was relatively easy to accomplish. Ability to initiate turn rate was good. Ability to stabilize and hold preselected turn rates and to stop on a preselected heading was good. It was moderate to less than moderate in sensitivity to wind during the turn-over-a-spot. Crosswind turns into the wind - time to accomplish the maneuver was not excessive. There was, once I got used to the system, little tendency to overshoot or undershoot and ability to hold heading and position over the spot was good.

Control activity was not excessive. Control power seemed adequate. Precision hover was easy to establish and relatively easy to maintain. There were some random movements, but they were very low frequency and therefore easy to monitor and control. Attitude and angular rates were easily controlled. Position was maintained very well. It was adequate for vertical landings. Control activities were minimal for this type of maneuver. Quick stops were accomplished as quickly as I preferred. Excessive attitudes were not required. Ability to hold heading and altitude was good. Control motions were not excessive. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features would be the relative sluggishness and response to control input and, therefore, a lack of feeling of real good maneuverability. Favorable features - it was smooth reacting and fairly predictable when the pilot learned to anticipate the time delay and sluggish response to control inputs. No particular pilot techniques were required.

CASE 313

$X_u = Y_v = -0.05$ $\lambda = 0.374$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.028$

$M_q = L_p = -1.147$ $\zeta = 0.400$

$M_\theta = L_\phi = -1.308$

PILOT D PR = A5 $M_\delta = 0.709$ $L_\delta = 1.062$

Generally, this configuration longitudinally seemed as if it were stable in that axis; apparently it wasn't damped and it appeared laterally unstable. A medium selection of sensitivities was chosen which seemed to give the response desired for control.

Air-taxi-around-the-square - fairly easy to initiate motion; easier in the lateral direction than the forward motion. No particular difficulties holding in a preselected rate of movement forward. Going sideways there was a tendency to go a little faster than desired, and to have to adjust. No problem in stopping at the corners. A little overshoot going sideways. Attitude changes - moderate throughout most of the maneuvers. Ground track - no particular problem in maintaining the ground track. Control feel and forces okay. No comment. Corrections very small. No comment on trim. Fairly good response on control inputs for all axes. No comment on sensitivities. Had no difficulty in holding headings.

Turns-over-the-spot - seemed to maintain over the spot pretty well; no particular problems here, and no comments on the turn rates, etc.

Crosswind turns - there were no problems here. They were done quite fast in coming to a precision hover over a landing spot even though there was an apparent lack of stability laterally. It could have been landed vertically okay.

Quick stops - going forward, slight change was required; nothing excessive. Overshot slightly going with the wind sideways on the quick stop. Control motions again were minimal. No comments on secondary dynamics.

Overall Evaluation

The main objectionable feature was that the lateral stability left something to be desired. It did appear to be unstable laterally which was objectionable, and it does need improvement in that area. Favorable features - even though apparently it was not a real stable configuration, it was fairly easy to fly. No comment on special pilot techniques.

PILOT E PR = A2-1/2 $M_\delta = 0.586$ $L_\delta = 0.494$

General comments - I was quite happy with the model. It seemed very easy to fly and very solid and well-behaved. Only one minor complaint was that it seemed that I couldn't be quite as precise as I wanted to be in the position control.

Control sensitivities - I think I had the sensitivities just a little bit high so I was getting a little bit of a bump in pitch due to inadvertent tiny control inputs; but I don't think it affected my evaluation. The air-taxi-around-the-square - along the front lateral translation, I had some problem in holding a straight track. The vehicle seemed to want to drift back as I translated. On the left-hand corner, I couldn't really be as precise as I wanted to on coming to a hover. No problem with the attitude changes. So there was a slight problem in doing exactly what I wanted to in terms of the ground track. Control feel, forces, etc. - no problems.

Response to control inputs was good. There was some minor problem in controlling the heading in the lateral translation. Turn-over-the-spot - no problems. In the 90-degree crosswind turns, a whole lot of rudder was required to get around the corner. The precision hover was the only area of complaint and that was in maintaining and going to a selected position. I couldn't be as precise as I wanted to be. Certainly adequate for a vertical landing. Control activity - no particular problem. Quick stops - I could stop as quickly as I wanted to. Attitude changes - nothing stood out to me. Heading, altitude - no problems. Control motions - not a factor.

Overall Evaluation

Objectionable characteristics, objectionable features - just a lack of fine precision in holding position. Favorable features - attitude selected for a given control input had no overshoot and it felt very solid. Control responsiveness was good. No special piloting techniques required.

PILOT F PR = A3 $M_\delta = 0.366$ $L_\delta = 0.379$

This control system was reasonably well-behaved. It was slightly sluggish because of the required lessening of control sensitivity for proper control. It was moderately wind-sensitive. Overall, maneuvers were able to be performed in a reasonably precise manner and without undue pilot workload. The control sensitivity required a very low selection on the simulator in order to give an optimum response of the aircraft. Anything higher than this low setting made the aircraft a little too sensitive to control stick inputs and random wind effects. Because of the low sensitivity, I did have a slight sensation of sluggishness, but it was not too bothersome.

In the air-taxi-around-the-square maneuver, the ability to initiate motion in each direction was good. Ability to stabilize and hold preselected rates of movement were good also. I could stop precisely and come to a reasonably stable hover at the corners. Excessive attitude changes were not required. Ability to remain within the ground-track limits was good. Control feel, forces, deflections, and trimmability also were good. Response to control inputs - pitch and roll - was slightly sluggish, but required, in order to make the aircraft behave overall in a more predictable manner. Sensitivities were low, as stated earlier. Ability to hold heading was good.

CASE 314

$X_u = Y_v = -0.05$ $\lambda = 0.374$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.044$

$M_q = L_p = -1.785$ $\zeta = 0.700$

$M_\theta = L_\phi = -1.547$

PILOT D PR = A5 $M_\delta = 0.615$ $L_\delta = 0.951$

Selection of sensitivity - this particular configuration felt unstable; however, it didn't seem extremely difficult to fly. Therefore, the control sensitivity was not real high, about a medium setting.

Air-taxi-around-the-square - fairly easy to initiate the motion. After the motion was started, it required some concentration in attitude adjustments to maintain a preselected rate of movement forward, backward, and sideways. Excessive attitude changes were not required. No particular difficulty maintaining within the ground track. There was a little difficulty stopping precisely at the corners, especially when tracking sideways. Control feel - no comment. Deflections were minimal with the particular control sensitivities that were selected. Response to control input was thought to be good on all axes. Good lateral response. No comment on sensitivities. No particular difficulty in holding headings.

Turns-over-the-spot - could maintain over the spot pretty well during the 90-degree turns. Attitude control of pitch and roll was satisfactory during the turns and there was no difficulty in initiating turn rate, stabilizing and holding the turn rate, and stopping on the heading.

Crosswind turns - quite easy. There was no tendency to overshoot. After the turns were made and the vehicle was established in a hover, very small control movements were required to hold in the hover to maintain position over the ground.

Quick stops were satisfactory. No particular comments there. Secondary dynamics - don't believe they had any effect on the evaluation.

Overall Evaluation

The objectionable feature of this machine was the lack of stability; however, with the control response that it did have, it was a fairly decent machine and only minimal control was necessary. But it was obvious that attention must be given to the vehicle at all times because of the lack of stability. Favorable features - the control response was favorable. Special piloting techniques - no comments.

CASE 313 (Continued)

The ability to remain within the ground-track limits was average. Control feel was a little bit loose to this pilot. Forces were OK. Deflections were not excessive and the aircraft could be trimmed up, but the complete combination was that it was a little bit looser system than would be considered ideal. Response to control inputs was a little bit slow. It took too long from the time I wanted to start a movement until I put the control in and the aircraft responded to the movement. Sensitivities were not objectionable. Ability to hold heading was good.

Turns-over-the-spot and ability to remain over the spot were average considering the wind effects and the sort of looseness in the control system. A fair amount of pilot attention to attitude, and a certain amount of control inputs into the pitch and roll axes to control the attitude and correct for movements due to wind, were required. Ability to initiate turns, ability to stabilize and hold preselected turn rates, ability to stop on preselected headings all were good. In the turns into the wind, the time to accomplish the maneuvers was considered average. There was a slight overshoot or undershoot tendency because of the slight unpredictable response to control inputs due to the time lag from the time I wanted to start slowing until the end results. Ability to hold position and heading over a spot was good.

Control activity was not considered excessive. Control power was adequate. Precision hover could be reasonably established and maintained. If a change in the attitude came before the aircraft responded to control inputs, it required slightly higher than average pilot workload in order to maintain a precision hover. However, I would consider the hover task as being reasonable. It was adequate for a vertical landing; nothing outstanding, but not too bad either. Control activity for hovering maneuvers was not really excessive. I would say it was probably less frequent and of a little larger amplitude than some other control systems. Quick stops were performed in a reasonably quick manner. Excessive attitude changes were not required, although I could probably attain a little bit larger attitude with this control system than I would with a tighter system. Ability to hold heading and altitude was average. Control motions required were not excessive or exaggerated. I don't believe the directional or height dynamics affected the evaluation.

Overall Evaluation

Objectionable feature was the time lag between initiating a control input and the end result of movement of the vehicle over the ground or attitude change. In other words, it was fairly slow in attaining an aircraft attitude change to a control input and then it was a fairly long time before the attitude change would result in a corresponding movement over the ground. Favorable features - it was a smooth control system. It was not jerky at all, and fairly predictable, but it did require anticipation due to the time lag within the system. No particular piloting techniques were required.

CASE 313 (Continued)

PILOT E PR = A3 M_{δ} 0.330 L_{δ} = 0.251

I liked it - only complaints were the attitudes required to generate velocities and it seemed to slide around in position a little more than I'd like, due to external disturbances. Control sensitivities - no problem.

Air-taxi-around-the-square - tended to have a fairly large trim attitude (a little more than I'd have liked) and the attitudes required to initiate and stop translation were larger than optimum, though the control capabilities were such that there was no problem doing the job as precisely as desired. So the attitude changes were maybe a little large, but the control response and the general feeling of the model were such that I didn't mind using large attitudes. Holding heading wasn't a problem.

Turn-over-the-spot didn't seem to present any particular problem. Crosswind turn - no comments. Precision hovering - no problem with the real problems of the attitudes although I seemed to have to use a reasonable attitude to trim off the wind. It actually didn't present a problem in attitude. Position was a bit sloppy - thought there was some influence of the external gusts. Certainly easy to land. Control activity was normal. Quick stops - they were very nice. Could certainly stop the machine very quickly and large attitude changes could be used with confidence.

Overall Evaluation

Objectionable features I think I've outlined. Favorable features - felt good and solid and there was no hesitation in using large, fast inputs.

PILOT F PR = A4 M_{δ} = 0.662 L_{δ} = 0.705

This was sort of a random type of control or loose control system which gave this pilot the general feeling that he had control of the aircraft but not all of the time, that it had a mind of its own and once in a while it would start to wander off. It required a certain amount of pilot attention and control inputs to bring the aircraft back to where the pilot wanted it or to continue the maneuver that he was conducting. Control sensitivity was pretty much of a moderate value in order to give the aircraft reasonable quickness in response but yet not be too oversensitive to small control inputs.

In the air-taxi-around-the-square, the ability to initiate motion in general terms in each direction was good. I couldn't always stabilize and hold the preselected rate of movement that I wanted. I might start out with it, and then it would slow up or speed up, and I would have to go ahead and adjust it. Ability to stop precisely and come to a hover at the corners was average, but nothing outstanding. It took quite a bit of anticipation as to when to put the control movements in to make the aircraft stop. Excessive attitude changes were not required, although I would say the attitude changes for rates of movement were larger with this control system than would be completely desirable. To start moving I would put in a fair amount of control input. Then the aircraft slowly attained the nose-down attitude and started moving over the ground. The whole process took a little longer than a pilot would desire.

CASE 314 (Continued)

In the turns-over-a-spot, I could remain over the spot as long as I reasonably anticipated the wind effects. Attitude control in pitch and roll was average. Ability to initiate turn rates was good. Ability to stabilize and hold preselected rates also was good, as well as to stop on preselected headings. Turns into the wind - time to accomplish the maneuver was normal. Minimum undershoot/overshoot tendencies. Ability to establish a position over the spot was very good. Control activity was minimal. Control power was felt to be adequate. Ability to establish and maintain a precision hover was also good. It did take some amount of pilot attention to small attitude changes and small inputs into the control stick in order to control the small attitude changes that did occur, to maintain the precision hover. It was very adequate for vertical landings, and control activity in the precision hover was good. Quick stops were performed reasonably fast. Excessive attitude changes were not required. Ability to hold heading and altitude was good. Control motions were not excessive. Secondary dynamics seemed not to enter into the evaluation.

Overall Evaluation

Objectionable features: the slight sluggishness in response due to the reduced control sensitivity of the simulator was somewhat degrading. It was moderately wind-sensitive and required a fair amount of pilot attention or control inputs in order to maintain a precise hover. Favorable features: it was quite predictable. The pilot had reasonable control of the aircraft in order to establish rates at his discretion, and in order to perform the required task. No special piloting techniques were required.

CASE 314 (RERUN)

$X_u = Y_v = -0.05$ $\lambda = 0.374$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.044$

$M_q = L_p = -1.785$ $\zeta = 0.700$

$M_\theta = L_\phi = -1.547$

PILOT E PR = A4-1/2 $M_\delta = 0.830$ $L_\delta = 0.851$

It was difficult to be very precise with this model, primarily because of the disturbances feeding through in pitch attitude, most noticeably, but also in roll. The position control was affected by this. Also, the attitude changes required to stop pitch, in particular, were large. I continually found myself inadvertently hitting the simulator stops in pitch, so I didn't like the attitude required to stop in pitch.

No comment on the control sensitivities. Motion was initiated easily in the square pattern and one could stabilize and hold a preselected rate of movement. Couldn't stop as precisely as I'd like to. Generally tended to use more attitude change in roll than in pitch, so there was a greater tendency to overshoot the mark in lateral translation because I would build up a larger velocity. So, the ability to stop precisely was not good, and hovering was affected by the disturbance levels coming through. Attitude levels, particularly in pitch, were excessive. Several times hit the simulator stops in pitch in rather innocent-looking quick stops. Could remain within the ground track easily. Feel, forces, deflections - nothing noticeable there. Trimming in and out of wind didn't seem to be a problem. Response to control inputs was good in both axes. Turning-over-the-spot - it was difficult to be precise because of the disturbances feeding through the pitch and roll. Most noticeable seemed to be the pitch attitude disturbances. But there was a general feeling of a lack of precision in position control.

Crosswind turns - same problem as outlined with attitudes in pitch. Had to use large attitude changes in pitch to stop. No problem with the control power. Control activities were not a factor. Precision hover was difficult for the reasons previously outlined. Certainly could have landed. Control activity was moderate. Quick stops - couldn't stop as quickly as I'd like to; another way of stating it is that the attitudes required to stop quickly were large enough that I was hitting the stops on the simulator in pitch. Heading, altitude - not of concern. Control motions weren't noticeable.

Overall Evaluation

The objectionable features - the turbulence disturbance level was high, which contributed to a lack of precision in the hover; and the attitudes required to stop the vehicle were large enough that I ran into problems with the simulator stops and I didn't like that. So, out of all this, it was controllable and acceptable but unsatisfactory.

CASE 315

$X_u = Y_v = -0.05$ $\lambda = 0.374$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.059$

$M_q = L_p = -2.443$ $\zeta = 1.000$

$M_\theta = L_\phi = -1.794$

PILOT D PR = A5 $M_\delta = 0.483$ $L_\delta = 0.369$

With this particular configuration, it was possible to fly the mission without excessive manual difficulty. Control sensitivity was a little low. The selection made seemed to give the best control harmony. The air-taxi-around-the-square seemed difficult to control. It was difficult to initiate forward motion and to stabilize a preselected rate of movement forward or backward. Stopping was no problem and the sideways movement was no problem. Excessive attitude changes were not noted during this pattern.

Ground track - going forward or backward, it was extremely difficult to stay on the track directionally. Control feel was okay. Forces were not excessive and deflections were felt to be about right. Trim okay. Control response seemed okay, possibly a little bit sluggish.

Turns-over-the-spot - there wasn't an excessive amount of difficulty here. Pitch and roll - seems as if there was quite a bit of nose-down required, especially going into the wind. No problem establishing the turn rate or holding the selected turn rate. There was no difficulty in stopping on a preselected heading.

The 90-degree crosswind turns - no problems noted here. No undershoot or overshoot tendencies and control activity was about moderate. Precision hover worked out pretty well. Attitude control seemed fairly easy when trying to stay over a specific point. Did feel adequate for vertical landing.

Quick stops - no problem here - either going forward or sideways with the wind and against the wind. Stops were felt to be okay and quick enough. No comments on the directional and height dynamics.

Overall Evaluation

The main objection to this configuration was to hold the ground track in going forward or backwards. Favorable feature was that it was fairly easy to hover; control movements were moderate throughout the planned mission. No special piloting techniques. Considerable pilot compensation was required to try to maintain the track reasonably well.

CASE 315 (Continued)

PILOT E   PR = A3 M_δ = 0.437 L_δ = 0.472

Pilot comments not available.

PILOT F   PR = A2 M_δ = 0.550 L_δ = 0.562

This was a very smooth, very well-behaved control system characterized by moderate wind sensitivity. Control sensitivity was pretty much of a moderate value, I would say, based upon an average to give reasonable response to the vehicle without oversensitive controls. It gave sort of a rough ride and the vehicle was too quick reacting.

The ability to initiate motion was very good with this control system. I felt that I could stabilize and hold preselected rates of movement much better than average. Ability to stop precisely and come to a hover at the corners was good. Excessive attitude changes were not required as I changed directions relative to the wind. Ability to remain within ground-track limits was good. Control feel, forces, deflections, and trim were all good. Responses to control inputs in all axes were pretty much to this pilot's liking in order to attain attitudes and rates that I felt I wanted. I could attain them fairly easily. Sensitivities were quite good. Ability to hold heading was good.

Ability to remain over a spot in a hover was good with a qualifying remark that it was moderately sensitive to wind effects; this was easily overcome with pilot inputs and anticipation. Attitude control in pitch and roll was good with some wind effects. Ability to initiate turn rate and stabilize and hold preselected turn rates was very good. I could easily stop on preselected headings. Ninety-degree crosswind turns - time was very nominal in order to execute the maneuver with very little overshoot and undershoot tendencies. Ability to establish heading and position over the spot also was very good. Control activity - there was plenty of control power available. Ability to establish and maintain a precision hover was very good.

Attitude and angular rates were easily attained and position over the ground was easy to maintain with minimum pilot attention to the attitude and minimum pilot inputs to the control stick. Control for a vertical landing was excellent. Control activity to establish precision hover and to maintain it was very minimal. Quick stops were easily and quickly accomplished without excessive attitude changes being required. I think I got up to 25 knots which was a reasonable airspeed and I was able to stop it without holding an excessive attitude for any period of time. Heading and altitude were reasonably easy to maintain. Control motions were not excessive. Secondary dynamics did not affect the flight.

Overall Evaluation

Objectionable feature was the wind sensitivity but it was not serious. It was a very smooth-flying control system, and it was easy to attain the rates and attitudes the pilot desired without any special piloting techniques required.

CASE 316

$X_u = Y_v = -0.05$ $\lambda = 1.320$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.500$

$M_q = L_p = -1.123$ $\zeta = -0.147$

$M_\theta = L_\phi = 0$

PILOT D PR = U7 $M_\delta = 1.093$ $L_\delta = 1.950$

On this configuration, the sensitivity was turned up on the controls because of the complete lack of stability longitudinally and, most noticeably, laterally when trying to fly.

Air-taxi-around-the-square - no particular problem on initiating motion either sideways or forward. Going sideways, it was more difficult to establish a rate of movement, strictly because of the lack of stability and the desire of the pilot not to lose control of the vehicle, especially laterally. There was also a tendency to overshoot at the corners when coming to a stop going sideways. No excessive attitude changes were required. It took complete attention to try to maintain the ground track. The sensitivity was turned way up because of the lack of stability. Real quick response was desired for minor movements of the control stick. Control response was adequate. No comment on sensitivities and no particular problem in holding the heading.

Turns-over-the-spot - remained over the spot fairly well. It did require considerable control movement in both pitch and roll to maintain position, especially after coming to a stop after each 90 degrees. No comments on the turn rates. No problem in coming to a stop on a preselected heading.

Crosswind turns were satisfactory. Here again, it took a lot of concentration to come to a precision hover and to hold heading in position exactly over the desired point. A vertical landing would probably be questionable in this particular vehicle.

On the quick stops - forward, no problem. Sideways with the wind there was a tendency, because of the lack of stability, to overshoot. Did not want to put in too much of a lateral input and risk losing control of the vehicle. No excessive control motions were required. No comment on the secondary dynamics.

Overall Evaluation

Overall objectionable feature was the extreme lack of stability both laterally and longitudinally - more noticeably, laterally. No favorable features. Special piloting techniques - no particular comment. Attention was required at all times to avoid losing control.

PILOT E PR = A5 $M_\delta = 0.436$ $L_\delta = 0.406$

This is another one of the models I didn't like. However, I'm not just certain why or how much I didn't like it. But, in general, it was very difficult to be precise. The model tended to slide around in position quite a bit. I assume this was due to external disturbances. I didn't seem to have any trouble with attitude. I had a feeling that I didn't want to throw the controls around very rapidly. Things were less than stable.

The control sensitivity - no comments. The air taxi - ability to initiate motion was no problem. There was a feeling that the vehicle was going to go too far in attitude so that I was a little cautious in my application of control. It was a little difficult to stabilize velocity, particularly laterally. I found myself going faster than I wanted to. I seemed to be able to stop reasonably precisely on the corners, although once again there was a feeling that one wanted to be cautious on how rapidly one used the controls. There was a tendency to overshoot. The attitude changes were about as much as I wanted to use. Occasionally I got close to the stops on the simulator.

No problem with the ground track. It tended to wallow a little in roll when I was trying to be precise on the longitudinal part. Response to control inputs was adequate. There was a little problem holding heading, due to this wallowing in roll. The turn-over-the-spot was rather poor because of disturbances in position. The attitude control - there was nothing that really bothered me. The 90-degree crosswind turns - a good deal of rudder coordination was needed to get around the corner. Otherwise, no comments. Precision hover - there was poor control of position. Attitude angular rates were okay. I think I could land it okay.

Control activity - there tended to be a lot of small inputs trying to keep the position as desired. Quick stops - I think I could stop as quickly as I wanted to. I was a little cautious with the control application for the reasons previously mentioned. So if I did try to stop abruptly, I usually ended up with a little residual oscillation that I could easily steady out. Excessive attitude changes were required. Considering the characteristics, they were excessive. A slight wallowing in roll made heading control on the longitudinal quick stop less than precise. Attitude was no problem. Secondary dynamics - no comment.

Overall Evaluation

Objectionable features - there was a feeling that one should be cautious in the control applications, particularly in pitch. There seemed to be an incipient instability there when I used controls rapidly. As far as the roll was concerned, there was a tendency to wobble around. Other objectionable feature was an inability to be precise in position in hover.

Favorable characteristics - in spite of the oscillatory instability, the oscillations or the overshoots could be damped out quickly. Special piloting techniques - the pilot should be careful in how rapidly he puts in control inputs. I would certainly like some improvement. I had to concentrate a lot to get any kind of performance.

CASE 316 (Continued)

PILOT F PR = A3 M_δ = 0.453 L_δ = 0.474

This was a relatively fast acting, sensitive control system, but overall had desirable characteristics and flyable characteristics. Control sensitivity was set at a moderate value to give the aircraft pleasant quickness of response without being overly sensitive to control inputs.

Ability to initiate motion on the taxi-around-the-square maneuver was good. It was a fairly sensitive control system. I could initiate motion fairly quickly. Ability to stabilize and hold preselected rates of movement was about average. It wasn't exceptional, but it wasn't bad either. Ability to stop precisely and come to a hover at corners was average. Excessive attitude changes were not required in order to initiate movement across the ground. Ability to remain within ground-track limits was reasonably good. I would say just about average for what we have been looking at. I think it was acceptable for the accuracy desired here.

The control feel was relatively light, forces were adequate, deflections were not excessive, and trimmability was good. Response to control inputs in the pitch and roll axes was quite sensitive with fairly fast response. Sensitivities were a little bit high but not overly so. Ability to hold a heading was good. Turns-over-the-spot - ability to remain over the spot was good. Attitude control required a fair amount of pilot attention but nothing excessive, and attitude control was reasonably well-maintained. Ability to initiate turn rates was good, as well as to stabilize on preselected headings. Time to accomplish 90-degree crosswind turns was normal. Overshoot and undershoot tendencies were normal. Ability to establish a heading and position over a spot turned out pretty well.

Control activity was not excessive. Control power was adequate. Precision hover was relatively easy to establish and maintain. It did require a fair amount of pilot attention to monitor the attitude control, and infrequent control inputs were required in order to maintain a position and attitude. Control was very good for a vertical landing. Quick stops were performed adequately fast. No excessive attitude changes were required. Ability to hold headings and altitude was normal. Control motions were not excessive in a quick stop. No secondary dynamics effects.

Overall Evaluation

Objectionable feature: It might have been slightly high in sensitivity of the control system. It did require a fair amount of pilot attention for attitude control, and the normal amount of inputs on the stick to maintain it for a fairly sensitive system.

Favorable features: It was responsive, it was easy to change the attitude of the aircraft, and it responded quite fast. It was not perfect, but not too bad for an acceleration system. No special piloting techniques were required.

CASE 316 (RERUN)

$X_u = Y_v = -0.05$ $\qquad \lambda = 1.320$

$M_u g = -L_v g = 0.33$ $\qquad \omega_n = 0.500$

$M_q = L_p = -1.123$ $\qquad \zeta = -0.147$

$M_\theta = L_\phi = 0$

PILOT E $\quad$ PR = A6 $\quad$ $M_\delta = 0.829$ $\quad$ $L_\delta = 0.851$

Crosswind turns - no problems noted. Precision hover - there were some disturbances in attitude which, combined with the instabilities, could lead to control problems in the hover with a little inattention in one axis. I think one could land it. Quick stops could be accomplished but the attitudes required to stop quickly were as large as I'd want to use. Control motions had to be fairly complicated to do what one wanted to do with the attitude. Secondary dynamics - no comments.

Overall Evaluation

Objectionable features were the divergence of small inputs in pitch and roll in the hover, and a divergent oscillation in attitude with motion. Favorable features - the quick response and no overshoots in pitch and roll allowed one to control the vehicle and do the task adequately. The divergent nature of the pitch and roll response in hover could lead to dangerous consequences.

CASE 317

$X_u = Y_v = -0.05$ $\lambda = 1.320$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.517$

$M_q = L_p = -1.477$ $\zeta = 0.200$

$M_\theta = L_\phi = -0.467$

PILOT D PR = A6 $M_\delta = 1.040$ $L_\delta = 1.791$

This particular configuration seemed very unstable laterally. It seemed that laterally it would fall off on one side or the other, like balancing on top of a pin. Pitch did seem to be stable. The frequency seemed pretty low. Because of the lack of stability laterally, the control sensitivities were turned up quite a bit on this particular configuration.

Taxi-around-the-square - no problem in initiating motion and no problem coming to a stop on the corners. Going sideways, it was necessary to watch roll so it wouldn't get out of hand. Ground track - satisfactory. Control deflections - had the sensitivity turned up quite a bit and used very little stick movement. Was constantly making corrections in flying this particular configuration. Response to control inputs may have been just a little slow in the pitch axis.

Turns-over-the-spot - considerable control activity here. Would have liked a little faster response in pitch.

Crosswind turn - time was very short, not excessive. Didn't overshoot or undershoot and precision hovers were satisfactory. Could have landed this particular configuration vertically, but had to watch roll at all times.

Quick stops - no problem here either stopping forward or sideways. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

The most objectionable feature was lack of stability in roll. Favorable features - nothing outstanding here.

Was able to fly the pattern okay, but it required pilot's attention at all times because of the lack of roll stability.

PILOT E PR = A5 $M_\delta = 0.910$ $L_\delta = 0.875$

There were some fairly objectionable deficiencies. The turbulence response was particularly annoying laterally. There were occasional large attitude changes due to external disturbances. The control response was kind of a lazy attitude system. After applying an input, a rate developed; and after centering the stick again, the attitude

would want to come out zero. So to hold a constant attitude, one had to play with the stick a little more than was desirable.

Air-taxi-around-the-square - initiating motion was no problem. Stabilizing and holding a preselected rate of movement - it was possible to do it. There was a lack of precision when trying to hover at the corners, and also in tracking over the ground. I was bothered with disturbances, particularly laterally. Attitude changes were not excessive. Very poor in staying within the ground track. Couldn't be precise in position. The response to a control input was a bit of a problem, as previously mentioned.

Turning-over-the-spot - there were no trim problems trimming out the wind, but the vehicle was disturbed in attitude and there was a general lack of precision in holding position.

Crosswind turns were easily accomplished. I had difficulty coming to a hover in roll. The roll control tended to give some control-induced oscillations. Control activity was more than normal. Precision hover - had troubles controlling the attitude and the position control was not good. Could be landed. Quick stops - attitude changes weren't excessive. Little problem holding the heading. Seemed to be disturbed in roll. Secondary dynamics were no problem.

Overall Evaluation

Objections were lack of precision in the hover due to external disturbances, particularly in roll, and a rather unusual control response which required a little more than normal control activity.

PILOT F   PR = A3 M_δ = 0.829 L_δ = 0.874

This was a smooth, responsive, maneuverable control system. It was characterized, however, by fairly frequent and constant random movement about the trim point. A precision hover could be established generally in the area I wanted, but there was constant pilot workload to monitor the attitude and almost continuous control inputs to maintain a stabilized attitude. There was no tendency for the aircraft to trim up and maintain a constant position. But the rest of the system was quite maneuverable and a good-feeling control system. Control sensitivity was a medium-high setting in order to give the aircraft proper quickness in response to control inputs and yet not be overly sensitive to small control inputs.

Air-taxi-around-the-square and ability to initiate motion in each direction were good. Ability to really stabilize and hold a preselected rate of movement was not good due to the random movements of the aircraft about trim. However, overall it was probably average. Excessive attitude changes were not required to accomplish the maneuver. Ability to remain within ground-track limits I thought was quite good. Control feel was real good in maneuvering. Forces were pleasant, deflections were moderate. However, it could not be trimmed to a hands-off condition, but this was not particularly degrading. I never held large control forces at any time. Response to control inputs was relatively fast and pleasant to this particular pilot and reactions to the control were good. Ability to hold a heading was also good. Turns-over-the-spot and the ability to remain over the spot were somewhat compromised by the continual random movement about trim. Attitude control in pitch and roll was easily maintained.

CASE 317 (Continued)

However, there were constant small-amplitude inputs in each axis to maintain attitude. Ability to initiate a turn rate was good, as was stabilizing and holding preselected turn rates and stopping on preselected headings.

In the 90-degree crosswind turns into the wind, the time to accomplish the maneuver was normal. Relatively little overshoot and undershoot tendencies. Ability to establish heading and position over the spot was good, considering that there was a small problem in maintaining exact position due to the random movement of the aircraft.

Control activity was normal. Control power was certainly adequate during the precision hover. Ability to establish and maintain precision hover was good in terms of general conditions. However, as mentioned before, there was a constant pilot workload to monitor precise position and introduce control movement to counteract random movements that the aircraft had. It was very adequate for vertical landings, and control activity was slightly above normal due to the random movements of the aircraft. Quick stops were accomplished as quickly as I preferred. Excessive attitude changes were not required. The ability to hold heading and altitude was good. Control motions were not excessive. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable feature of this control system was the random movement about trim position making very precise hovering more of a workload than it should have been.

Favorable features - it was smooth reacting, maneuverable, and gave the pilot a good feeling of confidence in maneuvering the aircraft. No special piloting techniques were required.

CASE 318

$X_u \quad - Y_v \quad = -0.05 \qquad \lambda = 1.320$

$M_u g = -L_v g = 0.33 \qquad \omega_n - 0.528$

$M_q = L_p = -1.692 \qquad \zeta = 0.400$

$M_\theta = L_\phi = -0.750$

PILOT D PR = A6 $M_\delta = 0.853$ $L_\delta = 1.442$

For this particular configuration, the gains were turned up a little because of the lack of stability. A little more authority with the stick, a little quicker response to the control movement, were desired.

On the air-taxi-around-the-square - it was fairly easy to initiate motion, but a little difficult to stabilize and hold a preselected rate of movement. Holding the movement going sideways was a little difficult because of the lack of lateral stability. It was difficult to maintain a preselected bank and hold it.

Precise stops sideways were a little more difficult. Excessive attitude changes were not required. Ground track was maintained within limits satisfactorily. Control feel was okay. Forces, no comment. The sensitivity was turned up to use small deflections for desired movements on the aircraft. Response to control inputs was good, and there was no particular problem on holding heading. No comment on sensitivities.

On the turn-over-the-spot - considerable pilot effort was required to maintain position over the spot. Pitch movements to maintain the proper attitude required effort. Turn rates, no problem. No problem in coming to a selected heading. Longitudinal attitude - it seemed as if it required a little too much attitude adjustment, especially turning into a wind. It required quite a bit of nose-down of the vehicle to maintain position.

Crosswind turns - no comment on the turn - there seemed to be a slight tendency with this configuration to undershoot and possibly go a little slower because of a lack of stability. No problem on establishing the heading and quite a bit of pilot activity was required in holding precision hover over the spot. Consequently, it was necessary to be aware of the vehicle in its attitude. Continuous inputs, both lateral and longitudinal, were required.

On the quick stops going forward - no problem. After the vehicle did come to a stop in the wind, the nose had to be pushed down to keep from going backwards. Attitude changes were not excessive, but not desirable. Quick stops required holding down the speed going with the wind because of the lack of lateral stability. There was a slight tendency to overshoot the spot to stop going with the wind - going into the wind was no particular problem. No comment on the directional and height dynamics. They didn't affect the evaluation.

CASE 318 (Continued)

Overall Evaluation

The prime objectionable features were the lack of stability, both longitudinal and lateral, requiring constant attention to maintain control of the vehicle. Did not see any particular favorable features in this machine. No comment on the special piloting techniques.

PILOT E   PR = A5 $M_\delta = 0.465$ $L_\delta = 0.498$

In general, I had a good deal of difficulty deciding on a rating for this model. I just couldn't decide how serious some of the deficiencies were. The principal problem was that with the velocities I generated, I was using fairly abrupt control inputs to stop precisely and had to command fairly large attitude changes. But the rate of change of attitude seemed to almost get out of hand at times, and as a result I ended up overcontrolling. So I tended to overcontrol and in one instance, which I put down to my being a little too abrupt, I did hit the stops. So there was an underlying tendency to overcontrol as the rates generated seemed to increase with time, with a given stick input.

The selection of control sensitivities - I certainly wouldn't want to fly with it more sensitive than I had it. The air-taxi-around-the-square - the ability to initiate motion was adequate. No problems there. Holding a preselected rate of movement required some effort, since the rate of change of attitude sometimes seemed to be divergent. The ability to stop precisely and come to a hover at a corner was somewhat compromised by the tendency to overcontrol with gross changes in stick position. The attitudes - I sometimes overshot the desired attitude. With a little bit of concentration I could do a good job with the ground track.

The control system didn't bother me. The control response was adequate. Initial response was adequate in both axes. Particularly in pitch, I noticed a tendency to overshoot the desired attitude. In other words, the rates built up a little faster than I'd like to have seen them. Turn-over-the-spot - I seemed to notice some tendency to slide around so the position control wasn't as good as I would have liked it. There seemed to be sliding in response to external disturbances. Turning in and out of the wind presented some problems in maintaining position. The 90-degree crosswind turns - I didn't notice any particular problem. Precision hover - position control was a problem. The attitude would change in direction in and out of the wind. It was noticeable, but not a real problem. I certainly felt that I could land it.

Control activity - I tended to have to use abrupt control motions. Quick stops - I think I could stop as quickly as I'd have liked to, except that I tended to overshoot the attitude. So I occasionally got excessive attitudes, both in pitch and roll, in the quick stops. I had some difficulty in controlling heading on the longitudinal quick stop. I tended to wallow in roll with the result that I sort of snaked down the track. Control motions required - the wallowing in roll when I was doing the longitudinal quick stop was noticeable. Directional and height dynamics weren't a factor.

CASE 318 (Continued)

Overall Evaluation

The objectionable features were a tendency to overshoot the attitude because of a greater-than-desired buildup in attitude rate, and there was some tendency to slide around with external disturbances making position control difficult.

Favorable features - I don't have any particular comments there. I did feel that without a great deal of attention, one could get himself in a position of too much translational velocity demanding an abrupt attitude change. Because of the sharp buildup in the attitude rate, one could get into a control problem by overcontrolling and getting close to the stops.

PILOT F PR = A3 M_δ = 0.456 L_δ = 0.569

This control system was moderately pleasant to fly. It was quite wind-sensitive to small upsets. The system seemed to require constant pilot attention to control small inputs into the control stick in order to maintain desired maneuvers, headings, etc. It seemed to have random upsets or random deviations. Whether it was from the wind or other characteristics, I'm not sure.

The control sensitivity was average, or normal, in order to give the vehicle position quickness in response, and yet not be overly sensitive. In the air taxi, maneuverability to initiate motion was good; however, I had difficulty in stabilizing and holding preselected rates of movement in order to maintain the path along the ground. There seemed to be continual small upsets or random movements which required constant correction and, therefore, it was difficult to maintain a track and a smooth rate of movement across the ground. Ability to come to a relatively precise hover was quite good at the corners. Excessive attitude changes were not required although many frequent small attitude changes were required in order to make the vehicle perform as required. Ability to remain within the ground-track limits was slightly below average.

Control force or feel was all right. The forces were normal. Deflections were moderate. Trimmability was good. Response to control inputs was reasonably fast. It seemed a little bit sensitive in terms of maintaining a given attitude. Ability to hold heading was good. In turning-over-a-spot, the ability to remain over the spot was pretty good. It was normal. Attitude control required constant attention to pitch control and roll control in order to maintain the attitude required to maintain the position over the ground. A relatively high workload was required for the turning maneuver. Ability to stabilize and hold preselected turn rates and stop on preselected headings was good. 90-degree turns into the winds - time to accomplish maneuver was normal. Overshoot/undershoot tendencies were average. Ability to establish a heading or position over a spot was normal.

Control activity I did not think was excessive for these maneuvers, and there appeared to be adequate control power. In a precision hover it was relatively easy to put the machine at the altitude and attitude desired, but it did require a constant pilot attention to attitude and frequent small amplitude inputs into the stick in order to retain attitude and position over the ground. It was adequate for a vertical landing,

and control activity was not of large amplitude, but of fairly high frequency. Quick stops were accomplished in normal time and with normal responsiveness; no excessive attitude changes were required. Ability to hold altitude and heading was good. Control motions were not excessive.

Overall Evaluation

Most objectionable features were the constant attention to maintain attitude, and frequent small control inputs in order to maintain the aircraft in a stable position. It had tendencies to fall off and move off in random directions.

Favorable features: maneuverable, fairly fast responding, and an average acceleration control system. Because of these random upsets, it left a little to be desired for complete pilot acceptance. No special piloting techniques were required.

CASE 319

$X_u = Y_v = -0.05$ $\lambda = 1.320$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.544$

$M_q = L_p = -2.031$ $\zeta = 0.700$

$M_\theta = L_\phi = -1.200$

PILOT D PR = A5-1/2 $M_\delta = 1.346$ $L_\delta = 1.317$

This particular configuration was flyable. The response was fairly fast and there was very little stick movement required for any maneuver to fly this configuration. It did seem unstable and did require continuous managing of a position to maintain control.

In the air-taxi-around-the-square, it wasn't too difficult to initiate motion. However, it was more difficult to maintain the preselected rate of movement both forward and when going horizontally backward. Stopping at corners, especially from forward or backward taxiing, required a little excessive longitudinal pitch movement; and it was fairly difficult to maintain the ground-track limits. However, it was within acceptable limits. Control feel - forces felt light. There was very little deflection for any response needed throughout the task. Response was fairly rapid. No particular difficulty in holding a heading.

Turning-over-the-spot - it took quite a bit of pilot effort, but there was no particular problem in turning over the spot. There was no problem in turn rates, or holding the turn rate or stopping on a preselected heading. At the stops there were considerable longitudinal and lateral control inputs in maintaining the position.

Ninety-degree turns into the crosswind - no particular problem here. Here again there was quite a bit of control activity after the stop when trying to do a precision hover, especially longitudinally. It seemed as if it took quite a bit of nose-down attitude to maintain a position into the wind.

Quick stops - forward into the wind - no particular problems were noted here. There seemed to be a tendency to overshoot and undershoot whether going with or into the wind. It seemed as if there was a tendency to overcontrol a little bit laterally. Directional and height dynamics didn't affect the evaluation.

Overall Evaluation

Objectionable features - here again, the configuration did seem fairly unstable and required constant pilot monitoring of position to maintain adequate control of the vehicle. The response was jerky and needed a little more control movement for the desired responses in each direction. Control power did seem adequate though.

No favorable features were noted in this particular configuration. The mission could be accomplished, but there were some objectionable features which should be

corrected. Special piloting techniques - the easiest way to fly it was to keep moving at all times, and use very light control pressures on the control stick and very minute movements.

PILOT E PR = A3 M_δ = 0.321 L_δ = 0.329

The general comments are quite favorable. No real problems flying this vehicle. Seemed to me that I'd rather have a compromise between longitudinal and lateral. Laterally, the vehicle seemed to accelerate fairly rapidly and it required fairly large attitude changes to arrest lateral translation. Whereas longitudinally, for the same sort of attitude change, the velocity was less than desirable. Selection of control sensitivities - no problems.

Air-taxi-around-the-square - the comments concerning the initiation of the motion are as above. It seemed to be a little difficult to initiate motion longitudinally. I would have preferred a little more translation for a given attitude; whereas the opposite was true in the lateral case. It tended to move a little faster than desirable and a large attitude change was required to arrest motion. Laterally, the machine tended to accelerate a little bit so holding a selected rate of movement was perhaps a little more difficult. No problems with precision and hovering at the corners because of the large lateral translational velocities. Some fairly large lateral attitudes were required to arrest the motion. Holding the ground track was not a problem; I thought I could hold it as closely as I wanted.

No problem with the control feel. Even though attitudes were sometimes large, control forces weren't bothersome. No problems with response to control motion. Sensitivities - nothing. No problems with the heading. Turn-over-the-spot - no particular problem noticed here. 90-degree crosswind turns - I think that I could do them about as well as I wanted to. Precision hover - no noticeable external disturbances. Hovering precisely was no problem; certainly, no problem to land it. No excessive control activity. Even in the lateral quick stops where the velocities got fairly high I felt that I had complete control to generate the necessary attitude to arrest the motion. Heading and altitude were not of concern. Control motions - no trouble even with the large lateral attitudes required. Secondary dynamics - not of interest.

Overall Evaluation

Objectionable characteristics were that the lateral velocities could get out of hand if they weren't watched carefully, resulting in large attitudes required to arrest lateral translation. Favorable characteristics - I didn't seem to be bothered with any external disturbances. No special pilot techniques required.

PILOT F PR = A4 M_δ = 0.828 L_δ = 0.841

This particular control system required a moderate amount of pilot attention to accomplish the test task and I feel that the tracking of the square pattern was a very poor pilot performance. I think I tried to fly a little too slow and it was more difficult to keep control of the track and rate of speed at the slower speeds than if I had accomplished the maneuver at a faster rate.

CASE 219 (Continued)

I felt that the control sensitivity had less effect on this particular control system, as to whether it was flyable or not, than some of the previous control sensitivity effects. In other words, it seemed to be flyable only at a much slower rate. Increasing the control sensitivity did not seem to increase the rate of response to a degree that it became unflyable, at least not as fast as this effect has been seen on some of the other control systems that I've looked at. So overall, I'd say the control sensitivity had less effect on this particular control system than on others.

On the air-taxi-around-the-square, I've already commented that I think that I attempted to fly it too slow. At a slightly faster rate than I accomplished it, the aircraft seemed to behave better. After flying the initial evaluation I went back and repeated the square task. Ability to stabilize and hold rates of movement was not as good at low speeds as it seemed to be at more moderate hovering speeds. Ability to stop precisely and come to a hover at the corners was fair - not outstanding but not bad either. Excessive pitch attitude changes and roll attitude changes were not required in order to accomplish the square task. Ability to remain within ground tracks improved with moderate hover speed. I did have difficulty on the task at the very slow speed as stated earlier.

Control forces, feels, deflections, and trim were quite good although they did tend to be on the sensitive side. I had to develop a fair amount of pilot attention toward the aircraft attitude and it took a very small stick deflection in order to correct or cause a change in attitude. Therefore the sensitivity in terms of attitude change was quite high. Ability to hold heading was good. Hovering over a spot required moderate pilot attention again toward controlling attitude in order to maintain position, and of course it required pilot anticipation for the wind effects. There were not any extreme attitude changes in pitch or roll during the hovering turns. Ability to initiate turns was reasonably good and I could stabilize and hold a preselected turn rate quite well. One could stop on a preselected heading at the pilot's discretion.

During the 90-degree turns into the wind, I could accomplish the maneuver quite quickly with this control system. It was quite responsive to control stick input with nominal overshoot and undershoot tendencies. I found it not too difficult to establish a rough heading into the wind over the predetermined spot. Control activity was not excessive and control power was adequate. During precision hover, I did have to direct a fair amount of pilot attention toward maintaining a level attitude although the attitudes were nominal and quite level for the wind effects. The control for vertical landing was considered quite adequate. Again, fairly frequent small control stick inputs were required in order to maintain a precision hover. Quick stops could be accomplished fast without extreme attitude changes. And I felt that the heading and altitude capability was quite good, without excessive control motions required. Secondary dynamics were reasonable.

Overall Evaluation

An objectionable feature was a reasonably fast reacting control system which required a fair amount of pilot attention to maintain a position over the ground at a level hover attitude. However, there was fairly good maneuverability from this quickness in response, and an ability to maintain a reasonable hover and not to diverge too quickly once a stable hover had been obtained. No particular special piloting techniques were required other than a tendency to have to make fairly high-frequency, small-amplitude control stick inputs in order to maintain a given attitude.

CASE 319 (RERUN)

$X_u = Y_v = -0.05$ $\lambda = 1.320$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.544$

$M_q = L_p = -2.031$ $\zeta = 0.700$

$M_\theta = L_\phi = -1.200$

PILOT E PR = A3 $M_\delta = 0.767$ $L_\delta = 0.789$

I spent a considerable length of time on this one. There seemed to be something that was bothering me but I couldn't figure out what it was. I certainly could do the mission adequately with little difficulty but there was a small tendency to overshoot in pitch and roll - maybe one overshoot; it really didn't enter into the accomplishment of the mission.

Sensitivities - no comments. Air taxi - didn't seem to have any problems initiating motion. Perhaps tended to overshoot the desired velocity in roll but could stop precisely and hover at the corners. External disturbances didn't bother me. Attitude changes in this phase were not excessive. Seem to have had to use moderate attitude changes to stop at the corners. Velocity built up fairly rapidly. Response to control input was satisfactory - slight overshoot, but not a problem.

Turning-over-the-spot was not a problem. Maybe some mild turbulence was felt in attitude, but it didn't present any control problem. Crosswind turns - no comments. Precision hover - could hover precisely; no outstanding problems with attitudes or position control. Certainly could land it. The quick stops - tended to overshoot the mark so I couldn't stop quite as quickly as I would have liked to; and the attitude changes required to stop were large, but still well within what was acceptable for this task. Secondary dynamics - no comments.

Overall Evaluation

Objectionable features - seemed to take off in velocity and roll at times. I really couldn't put my finger on what was bothering me and I could certainly do the job with a good deal of confidence in the vehicle so it was controllable, acceptable, and satisfactory.

CASE 320

$X_u = Y_v = -0.05$		$\lambda = 1.320$
$M_u g = -L_v g = 0.33$		$\omega_n = 0.560$
$M_q = L_p = -2.389$		$\zeta = 1.000$
$M_\theta = L_\phi = -1.672$		

PILOT D PR = A5 $M_\delta = 0.614$ $L_\delta = 0.920$

I believe this configuration was stable, but in pitch and roll there seemed to be a big lack of damping. No particular comment on control sensitivity. A medium sensitivity was selected.

Air-taxi-around-the-square - initiating motion was a little difficult because of the lack of damping longitudinally and laterally to initiate and stabilize on a preselected rate of movement. It seemed as if it had a tendency to overshoot the desired attitude. There was difficulty stopping at the corners both from forward movement and sideways movement. Excessive changes were not required, and the ground track was maintained okay. No comment on control feel or forces. Deflections were small. Response seemed satisfactory in all axes.

Turn-over-the-spot - could maintain position over the spot without too much difficulty. It required more pitch than roll changes, especially when turning into the wind. Quite a bit of nose-down pitch was required. No difficulty in initiating turn rate and so forth.

Crosswind turns - no particular problem here. Control power was adequate, and in precision hover, it seemed to be very satisfactory. Could have landed this particular configuration vertically. Control activity again was minimal.

Quick stops - no particular problem here. Excessive attitude changes weren't required. No excessive control motions were required. No comments on secondary dynamics.

Overall Evaluation

Objectionable feature was the lack of damping for roll or pitch. Favorable features - there was nothing really outstanding. It was a fairly decent machine as far as flying the mission - but not highly desirable. No comment on special piloting techniques.

PILOT E PR = A4 $M_\delta = 0.644$ $L_\delta = 0.536$

No real complaints. Control sensitivities - no comments. Air-taxi-around-the-square - motion could be initiated easily in either direction. Could be stabilized and moved with constant velocity. The precision with which I could stop it left a little to be

CASE 320 (Continued)

desired in pitch. Tended to overshoot the mark. Had to use very large attitudes to come to a hover. No problem remaining within the ground track.

Control feel and forces - no comments. Response in all axes was satisfactory as were the sensitivities. Turning-over-a-spot - no complaints. Ninety-degree crosswind turns - had to use lots of rudder to come around the corner, otherwise control activity was normal. Precision hover - no complaints. Quick stops - deficiency arose in pitch. Tended to have to use very large attitudes and be careful that I did not overshoot that attitude. The response built up very rapidly to a stick pitch input. Secondary dynamics - no complaints.

Overall Evaluation

Overall objections were the large attitudes required to initiate motions and particularly to stop them. Favorable features - I liked the roll better than the pitch.

PILOT F   PR = A2-1/2 $M_\delta = 0.742$ $L_\delta = 0.785$

This was a generally pleasant, well-behaved control system to fly. It was predictable and gave the pilot a sense of confidence in maneuvering the vehicle. A medium-high sensitivity was required on the controls in order to give the aircraft quickness in responding to the control system. At this higher sensitivity selection, there was a small spot around the trim point where it was easy to put in some small spurious inputs which made maintaining the attitude task just slightly greater than it would have been if a lesser sensitivity had been selected. Therefore, this higher sensitivity requirement introduced a small additional pilot workload to monitor attitude or rate movements.

In the air-taxi-around-the-square, the ability to initiate motion in each direction was good. Ability to stabilize and hold preselected rates of movement was good, with occasional adjustments for random input from the wind. Ability to stop precisely and come to a hover at the corners was good. No excessive attitude changes were required. Ability to remain within ground-track limits was a little better than average. Control feel, forces, deflections, and trim were all good. Trimmability was good. The control feel did have a slight sense of looseness around the trim point during a precision hover maneuver which occasionally introduced undesired control inputs inadvertently. Response to control inputs in all axes was good. Ability to hold a heading was good.

Turns-over-a-spot and the ability to remain over a spot were good. Attitude control in pitch and roll was easily controlled. It was moderately wind sensitive, requiring anticipation in attitude change as I made the various turns. Ability to initiate turn rates, stabilize on preselected rates, and stop on preselected headings was good. In the 90-degree crosswind turns, the time to accomplish maneuver was normal. Overshoot and undershoot tendencies were less than average. Ability to establish heading and position over the spot was good.

CASE 320 (Continued)

Control activity I think was normal for this type of maneuver and control power was adequate. Precision hover was easy to establish and maintain with the exception of small attitude changes introduced due to the looseness of the stick around the trim position. I think this was due to the relatively high sensitivity of the control. It was very adequate for vertical landings. It was very good for that maneuver, and control activity was slightly less than for precision hover maneuvers. Quick stops were performed as quickly as I would like, with no excessive attitude changes required, yet the maneuver could be accomplished quite briskly. Ability to hold heading and altitude was good. Control motions were not excessive. Secondary dynamics were not affected.

Overall Evaluation

The objectionable feature was just a slight sloppiness of the stick around the trim point; it was not seriously objectionable. The vehicle was moderately wind sensitive. Favorable features - it was smooth, predictable, and gave the pilot a feeling of confidence in maneuvering the aircraft. No special piloting techniques were required.

CASE 321

$X_u = Y_v = -0.05$ $\lambda_{\theta_1} = \lambda_{\phi_1} = 0$

$M_u g = -L_v g = 0$ $\lambda_{\theta_2} = \lambda_{\phi_2} = 2.000$

$M_q = L_p = -2.000$ $\lambda_{\theta_3} = \lambda_{\phi_3} = 0.050$

$M_\theta = L_\phi = 0$

PILOT D PR = A4 $M_\delta = 0.744$ $L_\delta = 0.961$

This particular configuration didn't seem stable, either in pitch or roll, but when it diverged it was real slow which made it fairly easy to control in both axes. Control sensitivity was about a medium setting.

The air-taxi-around-the-square - fairly easy to initiate motion and stabilize on a selected rate of movement. It was easier going forward than it was going sideways. No excessive attitude changes were required. Ground track was within limits. Control feel and forces - no comment. Deflections very small. Response to control inputs seemed satisfactory. No problem during the turns-over-the-spot or in maintaining position. Nose-down pitch was required when turning into the wind. There was no difficulty in initiating a turn rate or in stabilizing on a preselected turn rate or stopping on a preselected heading.

Crosswind turns - no difficulty here. Time was fairly fast in carrying out the maneuver, and precision hovers were fairly easy to maintain. Quick stops - no comments here. Secondary dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable feature was the lack of stability, both in pitch and roll. Favorable features - it was not too difficult to fly even though it was unstable.

PILOT E PR = A5 $M_\delta = 0.393$ $L_\delta = 0.409$

I really didn't like flying this model. It seemed to be on the verge of instability all the time. The control responses were adequate to control the vehicle, so there wasn't really a problem. Just a feeling that I had to monitor the machine at all times.

The control sensitivities - no comments. Air-taxi-around-the-square - the motion was certainly initiated very easily. As a matter of fact, it felt like it would go right over on its nose if I let it. A little bit of effort was required to stabilize at some preselected rate of movement. I found that with a moderate amount of effort I could bring it to a stop and hover precisely, although the degree of concentration was a little more than I would have liked for this task. Sometimes the velocities were such that the attitude changes required to stop were fairly large. I felt that I could

reasonably remain within the track limits with moderate effort. Response to control inputs was good enough to counteract the general feeling of instability, in both axes.

Turn-over-the-spot - no real problem in attitude control with the wind as I turned around. Ninety-degree crosswind turns were no problem. Precision hover - in general it seemed to be a little sloppy. The control effort was more than I would have liked to keep it over the spot. Could be landed and the position was maintained reasonably well, but the control activity was more than normal to do so. Quick stops were no real problem. Certain feeling of hesitation because of the feeling that there was instability present. Secondary dynamics were no problem.

Overall Evaluation

Objectionable features - I generally felt that the machine required an excessive concentration to do an adequate job. The favorable characteristics were that the control responses were more than adequate to take care of any problem.

PILOT F PR = A2-1/2 $M_\delta = 0.609$ $L_\delta = 0.621$

This control system was overall very smooth and precise, bordering somewhat on being a little sensitive. An average value of sensitivity was needed in order to give pleasant quickness in response to the control system, coupled with a less sensitive control to where just a small movement of the stick would give too fast an attitude change.

The air-taxi-around-the-square - ability to initiate motion was very good. On the initial leg of the pattern I was at a very slow rate, perhaps a little slower than normal. However, I found I was able to stay within the 5-foot path. I probably made a few more deviations than if I had been at a slightly faster rate. Ability to stabilize and hold a preselected rate was fairly good as was the ability to stop precisely and come to a hover at the corners. I overshot on stopping on the downwind leg, which I've done quite frequently in most of these evaluations, by just not putting the correct control soon enough to counteract the wind. But with proper anticipation I think a person could stop on a predetermined spot. One thing that complicated that particular maneuver was not knowing exactly when the vehicle was going to approach the spot when moving backwards. Going in the forward direction, it was no problem whatsoever.

Excessive attitude changes were not required although this particular control system was moderately wind sensitive. Ability to remain within ground-track limits was very good. Control feel, forces, deflections and trim were average, and not objectionable. Control inputs in all axes were good. Sensitivities were good and ability to hold heading was good. Turns-over-a-spot - ability to remain over a spot was good with proper anticipation of wind effects; otherwise, one might drift a bit. I did have to have a moderate attitude change in order to compensate for wind, although attitude control throughout the turns was considered good. Ability to initiate turn rate, stabilize, and hold preselected turn rates and heading was good.

CASE 321 (Continued)

Time to accomplish the 90-degree turns into the wind was average. I felt that I could do the maneuver as fast as I wanted, and the vehicle responded properly to control with very little overshoot or undershoot tendencies. And I was able to establish the heading and position over the spot as desired. Control activity was minimal with plenty of control power. Establishing and maintaining precision hover was above average. Control for vertical landing was above average; at least, it was very good.

Once established in a hover, it did take pilot attention to attitude changes and a moderate number of small inputs into the control stick to counteract small gust changes. However, control activity overall was low. Quick stops could be performed adequately fast and excessive attitude changes were not required. The ability to hold heading and altitude was good. Control motions were not excessive. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

There were no strong objectionable features. With the control sensitivity selected, it was a little sensitive. I did have to monitor attitude and put in small corrections in order to maintain a hover or a rate. But this was a minor objection.

Favorable features - it was a smooth flying control system. It reacted adequately fast and I was able to make the aircraft do pretty much what I wanted it to do. I felt it was a good control system for an apparent acceleration-type system. No special piloting techniques were required. I did give a fair amount of pilot attention to attitudes and did have to put in fairly frequent control inputs of a very small magnitude in order to maintain a precise hover or to make the aircraft maintain a rate that I desired.

CASE 322

$$X_u = Y_v = -0.05 \qquad \lambda_{\theta_1} = \lambda_{\phi_1} = -0.0307$$

$$M_u g = -L_v g = -0.005 \qquad \lambda_{\theta_2} = \lambda_{\phi_2} = 2.000$$

$$M_q = L_p = -2.000 \qquad \lambda_{\theta_3} = \lambda_{\phi_3} = 0.0819$$

$$M_\theta = L_\phi = 0$$

PILOT D PR = A4 $M_\delta = 0.569$ $L_\delta = 0.922$

This particular configuration was fairly easy to fly. Took quite a bit of stick movement, but performance was satisfactory.

Air-taxi-around-the-square - no problem on initiating motion or moving forward, backward or sideways. Possibly a little overcontrol of sideward movement of vehicle. No particular problem on hovering or stopping at the corners. Attitude changes were not excessive. Stayed fairly well within the ground track.

Controls, forces, deflection, and so forth - no comment. Response to control inputs was satisfactory. Seemed to be heavily damped in all axes. On the turns-over-the-spot - no problem. Pitch and roll control was satisfactory. Turn rate and so forth - satisfactory.

Crosswind turns - no problems. Coming to a precision hover after the crosswind turns was fairly easy. Was able to maintain pretty good position over a selected spot. Small stick inputs were used during the hover. Would have been adequate for a vertical landing. Quick stops - no problems. No comments on directional and height dynamics. No effect on evaluation.

Overall Evaluation

Objectionable features - possibly a little more hands-off stability would be desirable. Favorable features - no comments.

PILOT E PR = A4 $M_\delta = 1.120$ $L_\delta = 1.081$

There was something about this vehicle that I didn't like and that was that it commanded rates for stick inputs. I felt I was going to fall out one side or the other every time I put an input in. As far as doing the maneuvers, it required a little more effort on the controls, but I could certainly do the maneuvers as well as I liked. There seemed to be some annoying disturbances coming through in pitch attitude, which didn't affect the performance too much; more annoying than anything else.

CASE 322 (Continued)

Air-taxi-around-the-square - the ability to initiate motion, no problems. Stabilizing rates of movements required a little work on the controls, but it could be done. Could stop precisely enough and I was willing to use the attitudes required, even though I was conscious of being careful. Attitude changes - not excessive. Response to controls - specific complaint was that I didn't like it for the task as well as I liked some of the others; made me feel that I wanted to be cautious with it.

Turns-over-the-spot - no new problem with the wind in terms of attitude control, but the attitude, particularly pitch attitude, seemed to reflect some external disturbances. Ninety-degree crosswind turns were easily accomplished with perhaps more than normal control activity. No problem with the control power. Precision hover - only problem was the external disturbances coming through the pitch attitude. Certainly could land it. Quick stops - was bothered by tendency to be a little close to the forward stop of the simulator. The attitudes required to generate the velocity that I wanted in the quick stops got a little bit large. Large attitude changes were required to stop, but could be done easily. Many control motions were required as well as large control displacements to quickly generate the attitudes that were wanted.

PILOT F PR = A2-1/2 $M_\delta = 0.553$ $L_\delta = 0.569$

This was a smooth, pleasant, solid feeling control system. The vehicle responded fairly fast to an attitude change but then there was quite a delay between the time the aircraft changed attitude and the time it attained the full rate of movement across the ground. The rate of movement was very slow initiating and building up to its final rate, depending on where the stick was placed; so this introduced a compensation factor that the pilot had to consider. He'd have to put in a control movement, then guess what rate would finally build up, and then have to anticipate just where to put in the corresponding control input in order to make the aircraft stop where he had preplanned.

Control sensitivity ended up with a medium setting. Anything lower than this just made too slow a response of the vehicle even though it timed the rate movement a little closer to stick input; i.e., by slowing everything down, the aircraft was a little slower in attaining the attitude change but there was a little less apparent delay from the time the aircraft changed attitude until the aircraft started moving. In a way they were, then, more in line with each other. The response of the aircraft attitude change and the response in building up the rate of movement across the ground were just too slow to accomplish a maneuver. Going to a higher sensitivity increased the apparent time lag of control input to attitude change and the time lag between that and movement of the aircraft across the ground. So to hit a happy medium, I ended up with a medium sensitivity which made the time delay apparent, but not as apparent as if the selectivity was higher. It also gave a more pleasant and responsive attitude change to control stick input.

On the tracking maneuver - the ability to initiate motion in each direction was pretty good but complicated by the fact that when I put a control input in and got an attitude, I had to wait and see what rate I was finally going to end with. So the ability, once attained, to stabilize and hold a preselected rate of movement was to my liking. It was easy to hold; however, it was difficult to guess as to what the final rate would be.

CASE 322 (Continued)

Ability to stop precisely and come to the hover at the corners was pretty good because I soon learned to anticipate the time lag involved and was able to guess pretty well what was needed to make the aircraft stop where I wanted.

It was easy to stabilize the hover momentarily. Excessive attitude changes were not required. I thought the ability to remain within ground-track limits was quite good. Control feel - the response of the aircraft to control inputs felt good and solid and pleasant to this pilot. Forces were good. Deflections of the stick were not excessive. Trimmability was good. Response to control inputs in all axes, especially pitch and roll, has been pretty well covered. The aircraft responded and changed attitude to control inputs very pleasantly. However, the performance was too long in coming in terms of rates and movements across the ground. Ability to hold heading was good.

Turns-over-the-spot were slightly less wind-sensitive on average, because it did not seem to require too much of a pilot workload in order to compensate for the wind. Possibly this could be due to the learning factor of anticipating it automatically. Attitude control during the turns-over-the-spot were easy to accomplish. Ability to initiate turns, stabilize on preselected rates, and stop on preselected headings was good. Ninety-degree crosswind turns into the wind and time to accomplish the maneuver were not excessive. There were no serious undershoot or overshoot tendencies.

Ability to establish a heading and position over the spot was good. Control activity did not seem excessive. Control power seemed adequate. Ability to establish and maintain a precision hover was good. There were a few random stick inputs in order to maintain the hover from gust effects, but the pilot workload in order to maintain a precise hover was quite minimal. It was very adequate for vertical landing.

As far as the quick stops were concerned, I felt that I could stop as quickly as I wanted. I could initiate a comfortably fast rate across the ground. I think I attained a fairly steep attitude in stopping on the one into the wind. It wasn't necessary but it seemed natural. It was comfortable and easy to control. Ability to hold heading and altitude through all these maneuvers was good. Control motions were not excessive. I did not feel that directional or height dynamics affected the evaluation.

Overall Evaluation

The objectionable features were the time delay between changing the aircraft's attitude and realizing a rate of movement across the ground, and the length of time it took the aircraft to build up to the final rate depending on the stick displacement.

Favorable features - it was very smooth reacting and the aircraft change in attitude was very smooth and comfortable to pilot inputs. I thought the whole system was predictable and it gave the pilot a high degree of confidence in maneuvering as soon as he was able to adjust to the time delay factor.

CASE 323

$$X_u = Y_v = -0.05 \qquad \lambda_{\theta_1} = \lambda_{\phi_1} = -0.0492$$

$$M_u g = -L_v g = -0.010 \qquad \lambda_{\theta_2} = \lambda_{\phi_2} = 1.998$$

$$M_q = L_p = -2.000 \qquad \lambda_{\theta_3} = \lambda_{\phi_3} = 0.1017$$

$$M_\theta = L_\phi = 0$$

PILOT D   PR = A4-1/2 $M_\delta = 0.714$ $L_\delta = 0.994$

This particular configuration took quite a bit of control movement, especially in roll to make the aircraft do what was desired. Possibly roll was real low frequency and slightly divergent. Pitch seemed stable enough. Rather medium sensitivity setting. No real difficulties in controlling the vehicle.

Air-taxi-around-the-square - no problem initiating motion or stabilizing on the preselected rate. Going forward and going backwards, there was a tendency to speed up and slow down. Was hard to hold the rate because of lack of visual cues. Overshot a little going sideways. Excessive roll or lateral inputs were required to make the vehicle respond as desired. No particular problem in maintaining the ground track. Control deflections weren't real large. Control response regarding movement of the vehicle seemed okay in all axes. Turns-over-the-spot - no problem here. Seemed to stay in there pretty well.

For this particular configuration, no excessive pitch and roll attitude changes were required. Crosswind turns again proceeded real fast. Didn't overshoot or undershoot and precision hovers worked out fairly well. Overactivity here again in roll. Constant inputs on the lateral control. A slight oscillation would develop occasionally during the hover. No problem on the quick stops. Forward - it would stop real fast. The attitude change was not excessive. Sideways - here again overworked the roll a little bit. Tendency to overcorrect a little bit in roll. Secondary dynamics, no effect on the evaluation.

Overall Evaluation

Objectionable features - would like to see a more stable machine laterally. Favorable features - no comment.

PILOT E   PR = A3 $M_\delta = 0.459$ $L_\delta = 0.496$

It was quite pleasant to fly with a few minor exceptions. In general the pitch was more satisfactory than the roll. The roll tended to be a little wobbly but not excessively so. There seemed to be a divergent oscillation if I let it go. But with the quality of the control response and characteristics, it really didn't detract from the mission. The mission could be accomplished quite well.

The control sensitivities - no comment. The air-taxi-around-the-square - the ability to initiate and stabilize motion was good. Quick stops could be performed quite quickly and smartly at the corners, particularly in pitch. The attitude changes required were moderate - at least with this control system I wasn't hesitant to use the attitudes required. In roll it seemed to have, for small upsets, divergent attitudes and oscillation but I could quickly stabilize it straight and level any time I wanted to. The response to control inputs was good. No problem holding heading.

In the turn-over-the-spot there seemed to be a moderate attitude required to trim the wind out, but it didn't seem to show up in a problem hovering over a spot. In hovering over a spot there was a little bit of sliding due to external disturbances but it was not significant. Ninety-degree crosswind turns were easily performed - no problems. Precision hover - the attitude was no problem. Position was not as precise as I'd like to have had it but it was no problem. Certainly adequate for landing.

Control activity tended to be in short pulses. Fast movement of control was required. Same goes for the quick stops. Could certainly stop as quickly as I'd like and use fairly large attitudes, and get quick response so that I could stop the machine very nicely. Therefore, I didn't consider the attitude was excessive. The heading and altitude were no problem. Secondary dynamics - not of concern.

Overall Evaluation

Objectionable features - I think I've outlined them. Favorable features - certainly one could smartly correct any attitude or maneuver that was allowed to occur. In roll I could catch the oscillation and stop it at will. No special techniques required.

PILOT F PR = A3 $M_\delta = 0.634$ $L_\delta = 0.677$

This was a smooth, fairly pleasant control system to fly. It was mostly predictable but it occasionally had some random characteristics about it that introduced a slightly increased pilot workload in order to maintain constant rate maneuvers or constant hover.

Control sensitivity was an average value to permit reasonably quick-responding characteristics to the control inputs, but not excessively high; otherwise I would run into too rapid a response of the vehicle. In the air-taxi-around-the-square, the ability to initiate motion was good. Ability to stabilize and hold preselected rates of movement was basically good, but then there would be random inputs to the aircraft that would require pilot workload attention and control inputs to maintain whatever rates of movements I had set up. Ability to stop precisely and come to a hover at the corners was good. Excessive attitude changes were not required.

Ability to remain within ground-track limits was quite good. I had a little trouble on one leg in particular, but I don't feel it was because of the control system. I feel it was a little bit of pilot distraction and looking too closely to the vehicle and not to the horizon. Control feel was good. Forces, deflection and trimmability were all

adequate. Response to control inputs in the pitch and roll axes was pleasantly fast, without too long a time delay. It was average in that respect and to this pilot's liking. Controls were not oversensitive.

Ability to hold heading was good. Turns-over-the-spot and ability to remain over the spot were good. I had some trouble maintaining position, but again I think it was due to my inattention rather than the vehicle control system. Attitude control in pitch and roll was quite predictable and easily maintained by the pilot with the consideration of the random inputs, which I assume were from the wind velocities. I did have to monitor attitude control quite closely, so as to pick up the random deviations and correct for them with control inputs. Ability to stabilize, hold preselected turn rates, and stop on preselected headings was good.

In the 90-degree crosswind turns into the wind, time to accomplish the maneuver was normal. The control system gave me a fairly high degree of confidence in maneuvering the aircraft in the manner which I wanted. Overshoot and undershoot tendencies were not present. I think I overshot once on my turn into the wind, but I think that was my exuberance in establishing a fairly high rate of speed across the square and being a little bit slow in turning back into the wind. Control activity was normal, with control power adequate. Precision hover basically was easy to establish and maintain.

Consideration for the random inputs from the wind required fairly close monitoring of attitude and corrections with the control. It was very adequate for vertical landings. Control activity in a hover was good. There was no tendency to overcontrol, and basically it needed very little control movement except to correct the random movements from wind.

Quick stops were perfromed as quickly as I would have liked. Excessive attitude changes were not required. Ability to hold heading and altitude was good. Control motion required was not excessive in terms of magnitude or frequency. Directional and height dynamics did not seem to affect anything.

Overall Evaluation

Objectionable features were the random attitude changes in hovers and rate maneuvers. This was easily overcome with pilot attention. Favorable features - it gave the pilot a fairly good degree of confidence in maneuvering the vehicle, and was smooth and responsive at a pleasant rate. No special piloting techniques were required.

CASE 324

$$X_u = Y_v = -0.05 \qquad \lambda_{\theta_1} = \lambda_{\phi_1} = -0.2273$$

$$M_u g = -L_v g = -0.140 \qquad \lambda_{\theta_2} = \lambda_{\phi_2} = 1.963$$

$$M_q = L_p = -2.000 \qquad \lambda_{\theta_3} = \lambda_{\phi_3} = 0.3147$$

$$M_\theta = L_\phi = 0$$

PILOT D PR = A4 $M_\delta = 0.601$ $L_\delta = 0.884$

This particular configuration seemed fairly stable longitudinally; however, laterally it would fall very slowly in roll.

The air-taxi-around-the-square - no problem in initiating motion, easy on forward motion to maintain preselected rate. Going sideways was a little difficult. Had a slight tendency to overcontrol when trying to maintain a particular rate. Pitch changes were not excessive. Ground track was maintained fairly well. Control deflections - no comment. Response seemed okay, maybe just a little bit sluggish in pitch, but it didn't really affect the flying of the machine because it did seem fairly stable in pitch and heavily damped.

Turns-over-the-spot - no problem. Pitch and roll control satisfactory, and no problem in initiating the turn rate, or holding it, or stopping on the heading.

Crosswind turns - here again, a minimum amount of time was required. No overshoot or undershoot. Precision hover - had a slight tendency to oscillate a little bit in roll. Was able to stay over the spot pretty well. Would not have had any problem on a vertical landing with this particular configuration.

Quick stops - no problem coming to a stop. Neither attitude changes nor control motions were excessive. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features - would like to see a little more stability in roll.

Favorable features - no comment there. No comment on special piloting techniques.

PILOT E PR = A3 $M_\delta = 0.626$ $L_\delta = 0.596$

I seemed to have difficulty assessing this model, although I think generally it was good. No comments on the control sensitivities. The air-taxi-around-the-square was no problem longitudinally. To my surprise, I had a little difficulty laterally in stabilizing the movement. I could hover precisely at the corners.

CASE 324 (Continued)

The attitude changes were not excessive although, once again, in roll the velocity seemed to get larger more rapidly than I expected and so the attitude to arrest the lateral translation sometimes got large. The response to the control inputs was good so that any oscillations or overcontrol could be quickly damped out with control inputs. No problem holding a heading. I seemed to perhaps have some difficulty in the lateral translation, keeping the heading.

In the turn-over-the-spot - there were no problems with attitudes but there was some problem holding position. In the 90-degree crosswind turns - a whole lot of rudder was required to come around the corner. Precise hover and the attitude were no problem. The position was a bit sloppy. The vehicle seemed to slide around more than what could be called perfect. Certainly adequate for landing.

Control activity - no comments. Quick stops - could stop the vehicle as quickly as I would like. Pretty large attitude change was required; but, with the control response there didn't seem to be any particular problem generating the attitudes to bring the ship back to level flight. Heading, altitude, control motions - reasonable. Secondary dynamics - no comments.

Overall Evaluation

Objectionable feature was a little tendency to perhaps get divergent in attitude and translation. As far as the task was concerned, it was controllable, acceptable, and satisfactory. The unpleasant characteristics were classified as mild and it was sufficient for the mission without improvement.

PILOT F PR = A2 M_δ = 0.539 L_δ = 0.552

This was a pleasantly responsive and smooth control system, characterized by too much sensitivity. But a moderate amount of pilot attention was required to maintain precise hover and predetermined rates of movements. Control sensitivity was of an average value. This gave a very responsive control system, but one that was smooth reacting and fairly predictable.

In the air-taxi tracking maneuver - ability to initiate motion in a fixed direction was very good. Ability to stabilize and hold selected rates of movement was above average for this kind of a control system. Ability to stop precisely and come to a hover at the corners was above average.

Excessive attitude changes were not required throughout the maneuvers. Ability to remain within ground-track limits also was very good. I thought the control feel was better than average. Forces and deflections were normal, and trimmability was good. Response to control inputs was pleasantly good in all axes. Sensitivity was adequate, and not overly sensitive. Ability to hold heading was good.

In the turns-over-a-spot - ability to remain over the spot was above average. Attitude control in pitch and roll was easily maintained without undue pilot effort. Ability to initiate turn rates was good. Ability to maintain and hold selected turn rates and stop on preselected headings also was good. Ninety-degree crosswind turns

were accomplished in a nominal amount of time. Undershoot and overshoot tendencies were not existent. Establishing heading and position over the spot was easily accomplished with this particular system. Control activity was moderate and control power seemed adequate. I could establish and maintain a precision hover at my discretion.

A fair amount of attention was required to pick up and correct for small attitude changes which may have been induced by the wind. The pilot could easily overcome these small upsets and motions. With a minimum amount of effort,I could maintain a precise hover. It was very adequate for vertical landings, and control activity was moderate. Quick stops were accomplished in a normal manner with plenty of aircraft response. Excessive attitudes were not required. Ability to hold heading and altitude was very good. Control motions were not excessive. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Perhaps the only objectionable features were the amount of workload required to monitor the aircraft attitude, and the corresponding small control inputs required to maintain a predetermined attitude. I feel it was mostly wind induced. Favorable features: it was a pleasantly responsive, easily controlled system and did not require any special piloting techniques.

CASE 324 (RERUN)

$$X_u = Y_v = -0.05 \qquad \lambda_{\theta_1} = \lambda_{\phi_1} = -0.2273$$

$$M_u g = -L_v g = -0.140 \qquad \lambda_{\theta_2} = \lambda_{\phi_2} = 1.963$$

$$M_q = L_p = -2.000 \qquad \lambda_{\theta_3} = \lambda_{\phi_3} = 0.3147$$

$$M_\theta = L_\phi = 0$$

PILOT D PR = A5 $M_\delta = 0.853$ $L_\delta = 1.176$

This particular configuration seemed rather unstable, both in pitch and roll. In the air-taxi-around-the-square - initiating motion forward required a little too much nose-down attitude. Quite a bit of attention to pitch attitude also was required to maintain rate of movement. Lateral inputs to control roll also required attention due to a lack of stability. Stopping precisely at the corners worked out fairly well.

Quite a bit of control movement was required to handle the vehicle and make it do what was desired. Pitch and roll attitude changes during the maneuvers in the square which were required to achieve a motion or stop a motion, going forward or sideways, were a little excessive. Stayed fairly well within the ground-track limits. Could have done better if the vehicle had responded better. Control feel was okay. Deflections were okay. Response was satisfactory. Sensitivity okay.

In turns-over-the-spot - quite a bit of attitude adjustment was required both in pitch and roll to hold the position. Turn rates were okay. On crosswind turns, the first one was undershot; this could be attributed to the slow response of the vehicle to an attitude change. The second one worked out okay.

Numerous attitude adjustments and control activity were required. Precision hover worked out fairly well. While stabilized, there was still quite a bit of activity, laterally and longitudinally. Unable to keep vehicle real stable in the hover. Vertical landing probably could have been accomplished. On quick stops going forward, large attitude adjustments were required to make the vehicle stop. Sideways with the wind - too much bank was required to stop the vehicle's motion. Quite a bit of bank also was required going into the wind. Secondary dynamics did not affect the evaluation.

Overall Evaluation

The main objectionable feature was the lack of stability, both in pitch and roll. The pilot also had to exert considerable effort to achieve reasonable performance.

CASE 325

$X_u = Y_v = -0.05$ $\qquad$ $\lambda_{\theta_1} = \lambda_{\phi_1} = -0.5975$

$M_u g = -L_v g = -1.000$ $\qquad$ $\lambda_{\theta_2} = \lambda_{\phi_2} = 1.589$

$M_q = L_p = -2.000$ $\qquad$ $\lambda_{\theta_3} = \lambda_{\phi_3} = 1.058$

$M_\theta = L_\phi = 0$

PILOT D $\qquad$ PR = A7 $\qquad$ $M_\delta = 0.717$ $\qquad$ $L_\delta = 1.069$

This particular configuration was quite difficult to fly. It required a lot of concentration, many control movements, and constant stirring of the stick to fly the mission. On initiating motion forward, the motion was kind of spastic. The response was kind of funny in pitch. It seemed as if it would be slow responding and all of a sudden there would be a pretty good motion of the vehicle. It was difficult to hold and stabilize on a preselected rate of movement. No problem coming to a hover at the corners; however, there was a lot of stirring of the stick there. Pitch and roll attitude changes during this pattern weren't excessive. Stayed fairly well within the ground track. Control deflections were very excessive. Would like to see considerably more static stability built into the machine.

Turning over the spot, pitch attitude changes were possibly excessive. It seemed as if there were large trim changes in the vehicle, especially in longitudinal axis, depending on which way the vehicle was pointing with relation to the wind. Stick forces varied considerably longitudinally depending upon which way the vehicle was facing in accordance with the wind. Crosswind turns worked out okay. Precision hovers weren't too bad considering the control activity up to this point. Quick stops - on the forward one, it seemed as if it had negative static longitudinal stability. In other words, it was gaining air speed on the forward motion. It seemed necessary to pull back further on the stick as air speed increased.

Attitude changes were a little excessive on the forward quick stop. No problem on holding heading. Lateral quick stops worked out satisfactorily. Secondary dynamics, directional and height dynamics, didn't affect the evaluation.

Overall Evaluation

The most objectionable feature in this configuration was in the longitudinal control and response of the vehicle. Very unsatisfactory. No favorable features. No comment on special piloting techniques. It required much too heavy pilot concentration to fly it even though mission performance was probably acceptable.

PILOT E $\qquad$ PR = A6 $\qquad$ $M_\delta = 0.893$ $\qquad$ $L_\delta = 0.900$

I didn't like flying this configuration. It felt unstable at all times, as if with a little inattention it would roll right off in attitude; which it would, with small inputs. It would diverge or appear to diverge; sort of half an oscillation. Pitch and roll seemed very similar.

The air-taxi-around-the-square - could initiate motion easily, provided the attitude didn't get out of hand. With some complicated control inputs and short bursts, I could hold a preselected rate of movement and stop reasonably precisely at the corners. The attitude changes required were moderate. The problem was that to maintain a constant attitude, required a complicated use of the controls. Control deflections were a problem since I continually had to use the controls in short bursts to achieve a steady attitude. There were very large pitch attitude disturbances and the trim was continuously a problem, particularly in pitch. The response to control inputs in both pitch and roll was not desirable in that for a small input I would get what appeared to be almost a divergence. And I immediately had to counteract with a stick input in order to control the attitude. Just felt like it was almost running away.

The sensitivities were fine. No problem with heading. Turn-over-the-spot was a problem. With the large gust inputs in pitch, attitude was a problem to control. No complaints about the directional characteristics. Crosswind turns could be accomplished in a short time with no overshoot although there was a tendency to be a little cautious in generating the attitudes to stop or turn, since the vehicle felt like it was going to fall right over in the direction initiated by the control stick. The control activity was high. Control power was adequate.

Precision hover - position control was poor with large changes in pitch attitude. Difficulty in trimming throughout the turns. I think it could have been landed. The control activity was complicated and high. Quick stops - once again there was a feeling that with abrupt input the attitude might get away. Ability to hold heading and altitude - no problems. As far as stopping was concerned, I could stop quickly, but had to be careful that the attitude did not diverge. Control motions were complicated. A continuous series of control motions was required throughout. Secondary dynamics didn't enter the picture.

Overall Evaluation

The objectionable feature was a feeling of divergence for small inputs in both pitch and roll. There was a feeling of overcontrolling. I immediately had to correct in the opposite direction, so the control inputs got rather complicated to hold a constant attitude.

Favorable features - in spite of the apparent divergence, I could stop it with abrupt inputs, so I tended to fly with a series of short, sharp inputs and continuous control activity. So it qualified as controllable. Because the initial control response was so quick, I could control the feeling of instability. It had very objectionable deficiencies and improvements were needed. The best available pilot compensation was required to achieve reasonable performance.

PILOT F PR = A4 $M_{\delta} = 0.753$ $L_{\delta} = 0.770$

This particular control system was basically unpredictable. It made me apprehensive throughout most of the maneuvers, although basically it was fairly well-behaved and maneuverable and at times predictable. Then, at other times, it seemed to react in a different manner. I seemed not to be able to trim the aircraft

up initially and it seemed that I was holding random pressures during some of the maneuvers. I don't know where they originated. They didn't seem to correlate.

The control sensitivity was slightly above average; it provided a reasonably fast response to the vehicle without being oversensitive. Also, the winds during this evaluation seemed to be fluctuating more than normally - around 6 to 16 knots. It seemed to be more of a variation than in some of the other evaluations. Perhaps some of the large gusts and changes contributed to the feeling of unpredictability in this particular control system.

On the air-taxi-around-the-square, the ability to initiate motion was average. When I put in an input I wasn't quite sure what kind of rate I would realize. Stabilizing and holding a preselected rate of movement was quite a bit less than average. Again, I don't know whether it was because of the particular sensitivity to the wind and to the larger wind changes.

Ability to stop precisely and come to a hover at the corners was below average. I felt that I would overshoot and I just didn't have the capability of maneuvering the aircraft as precisely as I would have liked and predicting exactly the way the aircraft would behave to control inputs. Excessive attitude changes were not required. Ability to remain within ground-track limits was only fair.

Control feel - the forces and deflections seemed pretty good. However, during the maneuvers described previously, I was conscious of holding unusual forces and I didn't feel I was able to trim the aircraft out during the initial hovering very well. Maybe it was just that this particular system was much more sensitive trim-wise to different maneuvers. I normally only trim up and start the maneuvers and then hold whatever forces are required in order to complete the various tasks. Perhaps the trim in this particular system was greater than in others. It wasn't difficult to overcome. It was just that it was greater than average.

Response to control inputs in all axes was fairly predictable in attitude changes, but the rate of movement across the ground was not as predictable. Ability to hold heading was good. Turns-over-the-spot - ability to remain over the spot was fair due to holding various control forces, and probably due also to the extra guess-factor that seemed to be introduced. Ability to initiate turn rates was good. Ability to stabilize and hold preselected turn rates and stop on a preselected heading was good.

In the 90-degree crosswind turns into the wind, the time to accomplish the maneuver was not excessive. I could attain as fast a rate of movement across the ground as I wanted with normal control inputs. No serious overshoot or undershoot tendencies. Ability to establish heading and position over the spot was fair. It seemed that in order to accomplish that whole maneuver I did put in some rather large stick excursions and I had a tendency to overcontrol. I don't have a good explanation of exactly why. Control activity therefore was a little greater than normal. Control power was adequate. Ability to establish and maintain a general precision hover was quite good, but to sit there and hold a real precise hover required a fairly high pilot workload and fairly frequent control inputs. At least the pilot was conscious of them. Ability for vertical landings was good. Quick stop maneuvers - I felt that I initiated rapid movement as quickly as I liked. Excessive attitude changes were not required

for the maneuver. Ability to hold heading and altitude was reasonable. Control motions were not excessive. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features - the whole aircraft seemed to be slightly more unpredictable in terms of performance and response to control inputs. Whether it was from the winds or some innate features of the control system, I don't know.

Favorable features - the aircraft reacted in attitude quite well to pilot inputs but it certainly did not give the pilot a comfortable feeling of confidence in maneuvering the aircraft. I never had an extreme concern for loss of vehicle control, but I felt the precision of the various maneuvers was not as great as it should have been. No particular piloting techniques were required.

CASE 326

$X_u = Y_v = -0.05$ | $\lambda_{\theta_1} = 0$ | $\lambda_{\phi_1} = -0.0307$

$M_u g = 0$ | $\lambda_{\theta_2} = 2.000$ | $\lambda_{\phi_2} = 2.000$

$L_v g = 0.005$ | $\lambda_{\theta_3} = 0.050$ | $\lambda_{\phi_3} = 0.0819$

$M_q = L_p = -2.000$

$M_\theta = L_\phi = 0$

PILOT D PR = A4 $M_\delta = 0.618$ $L_\delta = 0.902$

This particular configuration seemed rather stable; however, the response just wasn't what was desired because of what appeared to be low frequency both in pitch and roll.

Air-taxi-around-the-square - no problem initiating motion, either forward or sideways. Was able to hold the rate of movement in both directions fairly well. Excessive attitude changes weren't required, and it was possible to stay fairly well within the ground-track limits. Control deflections were satisfactory.

Response to control inputs was satisfactory, but for some reason the flight of this particular configuration was not enjoyable. No particular problems in turns-over-the-spot. No excessive attitude inputs were required. Turn rate, holding the turn rate, and stopping on the headings were satisfactory. Crosswind turns were rather rapid, with no overshoot or undershoot. Precision hover after a stop worked out fairly well, with perhaps a slight lateral oscillation. It would have been adequate for a vertical landing.

Quick stops -- no comment. They worked out satisfactorily. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features - no comment. Favorable features - vehicle was rather stable, but required a little too much control to make it perform as desired.

PILOT E PR = A4-1/2 $M_\delta = 0.453$ $L_\delta = 0.467$

I didn't like it, but I find it difficult to say exactly what it was. However, I could do the job adequately.

Control sensitivities - no comments. Air-taxi-around-the-square - the ability to initiate motion was all right. I found some difficulty in being precise, particularly

moving laterally. I had trouble maintaining a track and coming to a precise hover. Attitude changes were moderate to arrest any velocity. I could do a moderately good job of remaining inside the ground track,but it required a great deal of concentration to do so.

Response to control inputs - no problem. Turn-over-the-spot - precision in remaining over the spot was moderate. Attitude control - there was some difficulty in trimming out the attitude changes with turn, but in general the turns-over-the-spot weren't overly difficult. The 90-degree crosswind turns - one was good and one was bad. There was a tendency sometimes to overshoot in the attitude. The control activity was more than desirable.

In a precision hover it was mostly the position control that bugged me. I didn't feel I could be as precise as I wanted to be. I felt I could land it. The control activity was more than normal, but I could stop as quickly as I'd like to. There was a little concern about the attitude running away at times, when using large abrupt inputs. Heading and altitude - no comments. Control motions were large and reasonably rapid. Secondary dynamics didn't enter into the issue.

Overall Evaluation

Objectionable features - the general inability to be precise in coming to a hover and in the hover, and the tendency to overshoot in attitude with large rapid control inputs.

Special piloting techniques - the control inputs tended to be fairly rapid. It could do the job adequately, so it is controllable and acceptable.

PILOT F PR = A2-1/2 $M_\delta = 0.416$ $L_\delta = 0.428$

This was a reasonably well-behaved control system, moderately responsive and predictable in making the aircraft behave in the manner desired.

Control sensitivity was selected fairly low in order to cut down the quickness of response to the control system, and give the pilot more time to modulate his control movements to attain the desired rates of movement. I think with any higher control sensitivity selection, the overall rating would have been degraded.

In the air-taxi-around-the-square, the ability to initiate motion in either direction was very good. I thought it was reasonably easy to stabilize and hold a preselected rate of movement. It was slightly wind-sensitive. Ability to stop precisely and come to a hover at the corners was nominal. Excessive attitude changes were not required. At times if I sort of forgot about the wind and got a little bit behind it, the attitude required to compensate for the wind was fairly large. However, it was not considered excessive.

Ability to remain within the ground-track limits was reasonably good. Control feel, forces, deflections, and trim were all normal. Response to control inputs on all axes was adequate. It had smooth response, with a tinge of sluggishness, but I

think that's what made the control system flyable with a reasonably good overall rating for control sensitivity.

Ability to hold heading was very good. Turns-over-the-spot -- I had to maintain a fair amount of pilot attention to the attitude and put in the corresponding attitude changes to correct for wind effects, but the ability to remain basically over the spot was good. Attitude in pitch and roll also was good. Ability to initiate turn rates, stabilize on preselected rates, and stop on preselected headings, was good.

In the 90-degree turns into the wind, time to accomplish the maneuver was normal. Overshoot and undershoot tendencies were nominal. Ability to establish heading and position over the spot was quite good. Control activity was not excessive, and control power seemed adequate for the maneuvers attempted.

Precision hover was reasonably easy to establish and maintain. It did require a fair amount of pilot attention to the precise attitude so that I could quickly pick up wind effects and put in the control corrections in order to maintain position and attitude.

The control system was very adequate for vertical landings, and control activity for the precision hover was normal. Quick stops were accomplished as quickly as I desired. Excessive attitude changes were not required. Ability to hold altitude and heading was good, and control motions were normal. I don't believe that secondary dynamics affected the evaluation.

Overall Evaluation

Objectionable features - a little feeling of looseness during a precise hover in order to maintain an attitude. I felt there was a little sloppiness in the stick, and this allowed some random movements of attitude changes to affect the aircraft. Then I would have to go ahead and make another small control input to counteract the attitude changes. Maybe gust factors were inducing these movements.

Favorable features - it was reasonably smooth and predictable system, but slightly sluggish due to the decreased sensitivity required from the simulator. No special piloting techniques were required.

CASE 327

$X_u = Y_v = -0.05$ $\quad \lambda_{\theta_1} = 0$ $\quad \lambda_{\phi_1} = -0.0492$

$M_u g = 0$ $\quad \lambda_{\theta_2} = 2.000$ $\quad \lambda_{\phi_2} = 1.998$

$L_v g = 0.010$ $\quad \lambda_{\theta_3} = 0.050$ $\quad \lambda_{\phi_3} = 0.1017$

$M_q = L_p = -2.000$

$M_\theta = L_\phi = 0$

PILOT D PR = A4 $\quad M_\delta = 0.574$ $\quad L_\delta = 0.736$

This particular configuration, if you released the controls, wouldn't stay stable; but it would fall off real slowly, either in roll or pitch. There was no particular problem in controlling it. Control sensitivity was intermediate. It did lack stability, since it fell off real slow, but it was easy to control.

Air-taxi-around-the-square - no difficulty in initiating motion, or stabilizing of the rate. However, there was a little more control movement than desirable. Coming to a stop at the corners - overshot going backwards. Attitude changes were not excessive, as far as pitch and roll were concerned. The ground track was maintained fairly well. Control feel and forces were okay. Deflections - had to use more stick movement than desired. Response to control inputs seemed okay in all axes.

Turns-over-the-spot - stayed over the spot pretty well. Pitch and roll control was adequate. Turn rate, holding the rate, and stopping on the heading were okay.

Crosswind turns - minimum amount of time was required; undershot on the first one, didn't quite get to the spot. No problem in establishing a precision hover over the spot, but had a little more control movement than would be desirable. Could have landed the machine vertically.

Quick stops - no particular problem here. Attitude changes were satisfactory; achieved quick stops. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features - the most objectionable was that a little more control stick activity was required than desired.

Favorable features - it was a fairly easy machine to fly, even though it didn't appear real stable.

PILOT E PR = A5 $\quad M_\delta = 0.469$ $\quad L_\delta = 0.485$

Pilot comments are not available.

PILOT F PR = A2 M_δ = 0.500 L_δ = 0.584

This was a good flying control system and fairly responsive. It didn't seem to be overly sensitive, and the pilot was able to make the aircraft perform pretty much as he wanted. It did require a reasonable amount of pilot attention to attitude and resulting corrections on the control stick in order to maintain attitudes. It was a little sensitive to gusts, but overall it was a good system.

In the air-taxi maneuver - ability to initiate motion was good. It was not outstanding in its ability to stabilize and hold a preselected rate of movement. Little random upsets would cause one to accelerate or decelerate and so it was difficult to hold what one really wanted. Ability to stop precisely and come to a hover at the corners was good. Attitude changes were not excessive. Ability to remain within ground-track limits was average.

Control feel, forces, deflection and trim were all good. Response to control inputs was to this pilot's liking. It was responsive, about the right amount of time lag. Sensitivities to control inputs were good and ability to hold heading was good. The selection of control sensitivities was moderate for the control settings used here - just a slightly higher setting than average, in order to give the aircraft quick enough response and not be oversensitive to control inputs.

Turns-over-a-spot - ability to remain over a spot was very good. Attitude, pitch and roll were good overall. Sometimes I got a little bit of overcontrolling in both pitch and roll. I think I looked down too close to the aircraft and got a little bit disoriented; until I reestablished and got the proper hover attitude, I was overcontrolling the pitch and roll axes. Ability to initiate a turn, stabilize on a turn rate, and stop on a preselected heading was good. Ninety-degree turns into the wind were normal. Overshoot/undershoot tendencies were nominal.

Ability to establish headings and position over a spot was good. Control activity I did not think was excessive, and there appeared to be adequate control power. Precision hover was relatively easy to establish and maintain. I did have to devote a fair amount of attention to the attitude to maintain position over the ground. Control for vertical landing was good. Control activity in a precision hover maneuver was very good. I would say there was a nominal amount of activity.

Quick stops were performed as quickly as I preferred. Excessive attitude changes were not required either into the wind or downwind. Ability to hold heading and altitude was average. Control motions were not excessive. Directional dynamics did not seem to affect the maneuvers.

Overall Evaluation

There were no objectionable features to this control system. It was slightly sensitive to the random upsets but not overly sensitive. Favorable features: nicely responsive, not overly quick and not too slow. I would say it was fairly ideal in that respect. No special piloting techniques were required. The overall system was not one I could take my hands off for any period of time, so it did require average pilot attention for the hover maneuvering task.

CASE 327 (RERUN)

$X_u = Y_v = -0.05$ $\lambda_{\theta_1} = 0$ $\lambda_{\phi_1} = -0.0492$

$M_u g = 0$ $\lambda_{\theta_2} = 2.000$ $\lambda_{\phi_2} = 1.998$

$L_v g = 0.010$ $\lambda_{\theta_3} = 0.050$ $\lambda_{\phi_3} = 0.1017$

$M_q = L_p = -2.000$

$M_\theta = L_\phi = 0$

PILOT E PR = A5 $M_\delta = 0.829$ $L_\delta = 0.851$

It was a very strange vehicle to fly. I felt there was something wrong, but I couldn't quite figure out what it was for a long time. When sitting in the hover, the response to control input seemed quite nice. Then as soon as I got moving both in pitch and roll, I tended to diverge off in the wrong direction and had to use further control inputs to stabilize the attitude. So with velocities it would seem to be unstable, although the control responses were adequate enough to perform the tasks quite well with a reasonable amount of pilot effort. Also the trim changes with wind were a little bothersome in the hovering turn. No comments on the sensitivity.

The air-taxi-maneuver-motion was initiated easily and some effort had to be put into stabilizing the velocity since the attitude tended to increase moving forward. Providing one put in the proper control inputs, one could initiate motion and fly the square quite nicely. There was a little lack of precision in stopping at the corners because the velocity tended to increase rapidly at times.

Excessive attitude changes were not required since I could get a reasonable velocity if I kept the attitude under control and small. I could remain within the track limits reasonably well. Control deflection was complicated but there was no problem with the magnitudes. Trim was not noticeably a problem in the square. Response to control inputs in the hover seemed fairly reasonable - like a sluggish attitude system.

Turning-over-the-sport - there was a problem with attitude control turning in and out of the wind and there were some very slight turbulence inputs so that in turning-over-the-spot, the precision was lacking. Ninety-degree crosswind turns could be accomplished fairly smartly, as the velocities would be generated quickly. Precision hover had problems with the attitude control - not major ones, but it made holding a precise position mildly difficult. Could be landed.

The quick stops - couldn't quite stop as quickly as I'd like to with reasonable attitudes. The velocities got large quickly. There was a tendency for the attitude to diverge at times, unexpectedly, when changing velocity rapidly. Attitude control was difficult. Secondary dynamics were not of concern.

Overall Evaluation

The objectionable features were the apparent instability with velocity which meant that one had to work fairly hard at controlling the vehicle attitude. The control response was such that the task could be performed quite well with a modest amount of pilot compensation.

There was a tendency throughout to wallow in roll. In the square pattern, the thing that was the most bothersome was a continuing oscillation just ever so slightly in roll. So just the general precision was lacking in roll when concentrating on another axis.

CASE 328

	$X_u = Y_v = -0.05$	$\lambda_{\theta_1} = 0$	$\lambda_{\phi_1} = -0.2273$
	$M_u g = 0$	$\lambda_{\theta_2} = 2.000$	$\lambda_{\phi_2} = 1.963$
	$L_v g = 0.140$	$\lambda_{\theta_3} = 0.050$	$\lambda_{\phi_3} = 0.3147$
	$M_q = L_p = -2.000$		
	$M_\theta = L_\phi = 0$		
PILOT D	PR = A5	$M_\delta = 0.720$	$L_\delta = 1.022$

This particular vehicle seemed to be stable in pitch. Frequency seemed low. Roll was close to being neutrally stable. Had about a medium selection on sensitivity for flying it.

Air-taxi-around-the-square - seemed as if it took quite a bit of nose-down attitude change to initiate a forward motion. After the motion was started, there was no particular problem holding it or going forward. Sideways, it was a little difficult to maintain a selected rate of movement. The pitch changes or roll attitude changes were not excessive. Ground track - tolerable on maintaining that. Control feel forces okay. Deflections - the sensitivity was turned up a little bit and deflections were quite small. Response to control inputs may have been a little slow on pitch and roll.

Turns-over-the-spot - stayed over the spot fairly well. Pitch changes were a little greater than desired. No particular problem in maintaining turn rates and so forth.

Crosswind turns - overshot on the first one. The time was minimal. No problem in establishing a hover on the particular heading, and the precision hover worked out fairly well.

Quick stops - into wind, no problem. Going sideways, both with the wind and into the wind, no particular problem. Attitudes were nominal. Directional or height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features - it was not as stable as desired. To make it do what was desired, continuous corrections were required to the control input. In forward motion, it required a little too much nose-down attitude change to achieve desired motions. Nothing of interest in favorable features.

PILOT E PR = A4-1/2 M_δ = 0.421 L_δ = 0.363

There was a tendency to wobble, particularly in roll, and a tendency to overcontrol small inputs. The rates seemed to build up a little more rapidly than expected.

Control sensitivities - initial selection seemed adequate throughout. The air-taxi-around-the-square - the rates built up with small inputs, and the motion that resulted was sometimes more than expected. It wasn't overly difficult to stabilize and hold a preselected rate of movement with some compensation. With a little extra concentration, one could stop precisely and hover at the corners.

Attitude changes were reasonable for selected translational rate. Seemed to do an adequate job of remaining within the track with a moderate amount of effort. No comments on the control system. The responses to control inputs - I already mentioned that the rates seemed to build up a little more rapidly than I liked. No problems with the heading control.

Turn-over-the-spot - remaining over the spot itself was no problem. Attitude control - it seemed a little wobbly, particularly in roll. Generally, there was difficulty when doing anything else but concentrating on a spot. There was difficulty in holding the attitude steady. Ninety-degree crosswind turns didn't take too long to accomplish but there seemed to be a tendency to undershoot the spot, because when pulling back on the stick to arrest the motion, I seemed to get more than I wanted. Occasionally ran into the stops on the simulator when excessive rates resulted with inadvertent large control inputs.

Precision hover - it wasn't a problem when concentrating on that alone. Would be no problem landing it, and the control activity was moderate. Quick stops - tended to overcontrol slightly and therefore stop short of the desired spot. Excessive changes weren't required but they sometimes resulted because the rate of attitude was excessive. Heading and altitude - no problem. Control motions - moderate. Secondary dynamics - no problem.

Overall Evaluation

Objectionable characteristics - tended to overcontrol and get excessive rates, more than I expected for a given control input. So the configuration generally felt wobbly, particularly in roll.

Favorable features - one could get used to the large rates that were commanded with a stick input. Once used to that, the vehicle could be controlled adequately.

PILOT F PR = A5 M_δ = 0.431 L_δ = 0.509

This was a strange control configuration. Overall it seemed, at times, that one could make the machine do what one wanted but it was very difficult to make it continue to hold a constant rate or constant heading. In other words, I could get it into the ball park and get it settled down momentarily; but then it seemed as if random upsets came along, or just very small movements on the control would set up undesirable changes in attitude or heading.

The control sensitivities were relatively low; in fact, I'd say quite low for this configuration to produce a combination which would be favorable in my opinion. Air-taxi-around-the-square - at times, it was easy to initiate a desirable track and rate but it was not easy to maintain it and make small corrections to optimize the track and rate. Therefore, it was strange in that I could come pretty close to it and think I had it and then with very small stick inputs or lack of them, I would pick up drifts from track and rate changes that I did not particularly want.

The ability to come precisely to a hover - actually I could come to it and initially establish it but then it was difficult to maintain the hover once I got there. At times I did encounter somewhat excessive attitude changes - not bad. But they were very low frequency and relatively easy to control and bring back to normal attitude. Control feel and forces, etc. - the whole system was somewhat sluggish. I felt it took a slow input and I needed to give the machine time to react in order to get the type of response that I wanted out of the aircraft.

Response to control inputs was a little bit slow. The sensitivities, as I stated earlier, were relatively low. Ability to hold heading - at times, it was quite good; that is, if I could get the machine set up and didn't encounter too much of a random disturbance, it would hold a heading fairly well but not for very long. Ability to remain over a spot was only fair due to some of the random upsets. I'd start out real well but it was not easy to maintain it during the entire time period of the turn.

Pitch and roll control - again, it was initially quite good but then at times I would get into a situation in which I couldn't hold exactly what I wanted. Ability to initiate turn rate was quite good. Ability to stabilize and hold preselected turn rate -- as far as the turn rate was concerned, it was good. However, maintaining position over the ground with roll and pitch was not so good. Ability to stop on a preselected heading was quite good.

Ninety-degree crosswind turns -- I felt that the time to accomplish the maneuver was average. Very few undershoot or overshoot tendencies as long as one took his time. Again, due to some of the random upsets in pitch and roll, it was not outstanding in ability to maintain a precise position over the spot. One could approach it but then find himself wandering. I felt throughout that once I had dynamic maneuvers going the way I wanted, they were fairly easy to maintain. However, when I got down to a stable hover or a constant-rate turn this was difficult to maintain.

There seemed to be adequate control power. Prolonged precision hover was relatively poor, both in position and in trying to correct back once I got out of position. Sometimes I had a little bit more attitude and angular rate changes than I would have preferred. Control was very adequate, however, for vertical landing. Control activity was fairly frequent but of low rate. When I put in a control correction, the vehicle was relatively slow to respond. It took a little time for the machine to achieve the attitude that was wanted; therefore, the activity was of a slow total rate.

Quick stops actually turned out much better than I would have anticipated from some of the difficulties I had in performing the square maneuver. That's what led me to make the statement that some of the dynamic maneuvers seemed to be easier to accomplish than the steady-state maneuvers.

Excessive attitude changes were not required in the quick stops. I think the altitude worked out fairly well.

Control motions required were not excessive, although I think if one did have to go to an extreme control position, one would find himself taking quite a bit of time to get the aircraft back under control again.

Secondary dynamics were not any problem.

Overall Evaluation

Objectionable features - steady-state maneuvers were difficult to maintain and, for some reason, the dynamic maneuvers seemed to work out more to my satisfaction than did some of the maneuvers in which I would try to go at a slow-steady rate. So that led to the comment that for some reason the dynamic maneuvers were quite favorable. The steady-state maneuvers were not as favorable as the dynamic type. If I could get the control stick and the attitude and everything stabilized out so that I needed no corrections, just very small, frequent inputs into the stick would maintain it. However, the whole system had a tendency to have a random upset at a fairly slow rate, but it was difficult to maintain a given attitude for an extended period of time.

CASE 328 (RERUN)

$X_u = Y_v = -0.05$		$\lambda_{\theta_1} = 0$	$\lambda_{\dot{\phi}_1} = -0.2273$
$M_u g = 0$		$\lambda_{\theta_2} = 2.000$	$\lambda_{\dot{\phi}_2} = 1.963$
$L_v g = = 0.140$			
$M_q \quad L_p = -2.00$		$\lambda_{\theta_3} = 0.050$	$\lambda_{\dot{\phi}_3} = 0.3147$
$M_\theta = L_\phi = 0$			

PILOT F PR = A3 $M_\delta = 0.771$ $L_\delta = 0.750$

This control system was pleasantly responsive to changes in control inputs by the pilot; however, the performance of the aircraft in response to attitude changes had too long a delay between the time the aircraft changed attitude and the time that the aircraft generated movement across the ground. It also had a fairly frequent random movement about any given trim position which increased the pilot workload in trying to maintain a stable hover or any constant rate of movement. But the control system itself was responsive and smooth reacting and, overall, not a bad system to fly.

Control sensitivity was set at a medium-high setting in order to give a pleasant response to control inputs in terms of quickness, without being overly sensitive and getting a jerky ride from small inadvertent control inputs. In the taxi-around-the-square, the ability to initiate motion was pretty good, but not as ideal as it could have been due to the character of the random movements it had about the trim setting. I would initiate a control input to maintain or establish some sort of rate but once I approached it, I always had to make some sort of constant adjustment to the control stick in order to try to stabilize on a rate or movement across the ground.

The ability to stop precisely and come to a hover at corners was fair, again complicated by the random movement about trim, which introduced rates that I hadn't really planned on. I could certainly make a stop in the area of the corners, but it was difficult to stop precisely and I did have a tendency to overshoot in one direction or another and especially in the downwind direction.

Excessive attitude changes were not required in order to attain a rate of movement. Ability to remain within the ground-track limits was about average. It wasn't outstanding, but certainly accurate enough for most hovering tasks. Control feel was pleasant on this particular system. The aircraft responded very nicely to control inputs. Of course, as I stated previously, the performance of the aircraft lagged too much behind the attitude change. It was difficult to trim the aircraft up especially for hands off. It had a tendency to fall off in one direction or another.

As previously stated, response to control inputs was pleasantly fast in the pitch and roll axes. Ability to hold heading throughout the maneuver was good. Ability to remain over a spot during turns was average or moderately wind-sensitive. The attitude changes required to compensate for the wind were quite easily accomplished by the pilot.

Ability to initiate turn rates, stabilize and hold preselected turn rates, and stop on preselected headings was good. There was constant control activity during this and the precision hovering maneuver in order to maintain a relatively stable hover, due to the random movements about the trim position that occurred constantly.

In the 90-degree crosswind turns into the wind, the time to accomplish the maneuver was not excessive; overshoot/undershoot tendencies were not severe. Ability to establish heading and position over the spot was quite good. Again, maintaining and pinning down a precise hover was more difficult than normal due to the random movements about trim.

Control activity, I did not feel was excessive, and I felt the control power was adequate. Ability to establish and maintain precision hover required a fair amount of pilot workload to monitor precise attitudes, and it required fairly constant stick inputs in order to correct for random movements that occurred to the aircraft. It was very adequate for a vertical landing - I didn't feel the control activity was excessive in amplitude, but it was moderate to moderately high in frequency.

In the quick stops, I felt that I could attain a rapid movement across the ground with the normal attitude changes that I like. Excessive attitude changes were not required to stop the maneuver. Ability to hold altitude and heading was good. Excessive control motions were not required. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features were the fairly constant and random movement of the aircraft about the trim position, and the time delay between attitude change and movement of the aircraft across the ground.

Favorable features: the aircraft response in terms of attitude to control inputs was pleasantly fast and to the pilot's intent. I felt that I had good control of the aircraft and a fair amount of confidence in my ability to control and make the aircraft do what I wanted. However, in terms of absolute precision, it was a little less accurate than some other systems I have seen.

No special piloting techniques were required other than to anticipate the delays inherent in this system between control input and vehicle response in terms of movement across the ground.

CASE 329

$X_u = Y_v = -0.05$ $\lambda_{\theta_1} = 0$ $\lambda_{\phi_1} = -0.5975$

$M_u g = 0$ $\lambda_{\theta_2} = 2.000$ $\lambda_{\phi_2} = 1.589$

$L_v g = 1.000$ $\lambda_{\theta_3} = 0.050$ $\lambda_{\phi_3} = 1.058$

$M_q = L_p = -2.000$

$M_\theta = L_\phi = 0$

PILOT D PR = A5 $M_\delta = 0.668$ $L_\delta = 0.977$

There were no great problems in flying this configuration, but it tended to roll a little off to one side or the other rather sharply. No particular problem as long as the pilot watched what he was doing.

No significant problems in pitch. Response may have been just a little bit slow in pitch. Air-taxi-around-the-square – no problem initiating motion in all directions. Rate of movement was a little difficult to hold going sideways. No particular problems coming to a hover at the corners. Pitch and roll attitude changes were satisfactory, and not excessive. Stayed fairly well within the ground track.

Control deflections weren't great at all. Response to control inputs may have been a little bit sluggish in pitch. No problems in the turn-over-the spot. Pitch and roll attitude adjustments were satisfactory. No comments on turn rate. Cross-wind turns were accomplished rather rapidly and didn't overshoot or undershoot.

Precision hovers worked out pretty well. There was a constant oscillation in roll in trying to maintain a particular position. Quick stops worked out real well. Attitude changes weren't excessive, and there were no problems coming to a halt. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features – the lateral were probably the greatest. Would tend to roll to one side or the other if attention was not paid to controlling the vehicle at all times. No special piloting techniques were required.

PILOT E PR = U7 $M_\delta = 0.656$ $L_\delta = 0.652$

In general, the lateral characteristics bothered me most, though I did have some difficulty in the quick stops with the pitch control and ended up in a little bit of an oscillation that actually hit the simulator stops a couple of times. I had a great deal of difficulty trimming it; it seemed to want to fall over one way or the other if I looked away for a second.

Continuously in the hover I had difficulty getting it trimmed laterally. Initiating motion was not a problem but slowing it down was a problem. It was difficult stabilizing at a preselected rate of movement. It seemed to pick up velocity very rapidly, both in roll and pitch. The tendency to go a little faster than I wanted it to made it difficult to come to a hover. It was more difficult to come to a hover in the lateral case. Longitudinally I was able to fly the square all right, and also laterally, but I was flying with a lot of effort to keep it slow. I seemed to have some difficulty stopping it laterally so that the attitudes required were fairly large. I could remain within the ground-track limits. Problems were encountered throughout with the trim laterally.

There are no complaints about the initial response in pitch and roll or the sensitivities. The final response to a control input was rather questionable. Turning-over-a-spot could be done reasonably well. There was a little trouble again with continuously trimming laterally. The 90-degree crosswind turns seemed to be fairly easy to perform. I think maybe the ability to accelerate faster helped this maneuver. One could get up speed in the 90-degree heading before turning in. It seemed to turn the corner more easily with the aileron alone. The precision hover certainly could be learned. The precision with which I could hold position was less than desirable.

The quick stops were the place I ran into the most difficulties. Two problems - (1) the velocity got fairly high quickly so that in trying to arrest a longitudinal quick stop I ended up overcontrolling, and (2) in positioning for the quick stop I ended up hitting the stops on the simulator. Laterally, there was a real feeling that I was going to fall off the edge of a cliff when I put in a control input. It was not a very comfortable machine to do lateral quick stops with, although they could be accomplished. Even with large attitude changes, it did not stop as quickly as I would have liked it to laterally. Secondary dynamics - no comment.

Overall Evaluation

Objectionable features - I have already outlined them. Special piloting techniques - I just did not like flying it, particularly laterally, and I tended to be putting in controls in an abrupt manner. I could not fly it smoothly. I could do the job but it had some major deficiencies. I felt that I had to concentrate a little harder than I would have liked.

PILOT F PR = A3 M_δ = 0.820 L_δ = 0.863

This control system reacted pretty well. The pilot was able to make the vehicle do the prescribed maneuvers fairly smoothly and pretty much at his command. However, there was something about the system that seemed to introduce an additional workload in order to make the vehicle behave as the pilot desired. Initially, it felt as if there was a long-time response from the time I put the control in until the vehicle responded. After a couple of minutes I was able to make the vehicle maneuver pretty much as I desired in terms of rate and direction of movement. Overall I will have to say it was a little bit sluggish in response but a smooth flying system and capable of getting the job done.

Control selectivity was selected to be medium high on the simulator to make the vehicle respond a little faster to control inputs, and yet not be overly sensitive and jerky in the ride. In the air-taxi-around-the-square, the ability to initiate motion in each direction was pretty good. After I put the control input in, I had to wait a short period of time for the vehicle to assume its rate. I think maybe that was part of the uneasy feeling about this system, but pretty soon I began to recognize what kind of rate I got with what kind of input.

Ability to stabilize and hold preselected rates of movement improved as I became more familiar with the system. It was average, I guess. It certainly wasn't outstanding and might be rated slightly below average. Ability to stop precisely and come to a hover at the corners wasn't as precise as I might like, but it was adequate to get the job done. Excessive attitude changes were not required for the tracking maneuver.

I think the system was capable of a little better performance than I gave in remaining within the ground-track limits. Overall, I would say it was about average. The slight delay between input and vehicle movement response gave somewhat of a peculiar feel; however, the forces, deflections, and trim were all normal. Response to control inputs about the pitch and roll axes sometimes seemed to be delayed too long, but at other times it seemed to be pretty good. The overall results of aircraft control seemed to be reasonable, so I will have to say response to control inputs was adequate. Ability to hold a heading during the maneuver was average.

In the turns-over-a-spot, the ability to remain over the spot was average. Wind effects were relatively easy to compensate for and attitude control was not too much of a problem in order to accomplish the turns. The turn rate could be initiated well and I could stabilize on the rates and stop on a heading.

Crosswind turns - time to accomplish the maneuver was not excessive. Undershoot/overshoot tendencies were no particular problem. Ability to establish a heading and position over a spot was good.

Control activity was normal, and control power seemed adequate. I could establish and maintain a precise hover with some random movement about the trim position but it was not bad. It was certainly adequate for vertical landings. Control was nominal for a hover maneuver. Quick stops worked out fairly well after I got going. I attained quite a steep attitude, not because the system required it but because I happened to encourage the attitude in order to stop a little faster than normal. I was able to maintain positive control over the aircraft at all times and the altitude remained quite close to 30 feet, so I would say the quick-stop maneuver was performed slightly better than average.

Ability to hold heading and altitude was good, and extreme control motions were not required in order to accomplish the quick-stop maneuver. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features - there was something about the system I didn't like; however, I was able to make the vehicle maneuver and make it perform to the

prescribed maneuvers reasonably well. I'm not sure whether there was a longer than normal time constant in the control system that the pilot automatically compensated for but really didn't like.

Favorable features - it reacted predictably and quite maneuverably to the pilot's desire, and maneuvers were accomplished reasonably well. No special piloting techniques were required.

CASE 329 (RERUN)

$X_u = Y_v$	$= -0.05$	λ_{θ_1}	$= 0$	λ_{ϕ_1}	$= -0.5975$
$M_u g$	$= 0$	λ_{θ_2}	$= 2.000$	λ_{ϕ_2}	$= 1.589$
$L_v g$	$= 1.000$	λ_{θ_3}	$= 0.050$	λ_{ϕ_3}	$= 1.058$
$M_q = L_p$	$= -2.000$				
$M_\theta = L_\phi$	$= 0$				

PILOT F PR = A4 $M_\delta = 0.773$ $L_\delta = 0.752$

Overall, this control system gave the pilot a slightly uneasy feeling because of its constant and unpredictable random movements about the trim point. This complicated all of the tasks somewhat, introducing an additional workload to monitor the attitude or rate, and to continually modulate the control system to try to counteract these random movements. I soon gained confidence that there was no problem in being able to maintain control of the vehicle, but there was always a certain sense of uneasiness introduced by these random movements. It was sort of a peculiar control system in that particular sense. However, overall performance of the pilot's capability to make the vehicle perform in the given tasks was quite good.

Control sensitivities were medium high in order to give the aircraft quickness in response to control inputs. Any lower sensitivity resulted in too sluggish a response to control inputs to accomplish the desired maneuver. In terms of air-taxi-around-the-square, the ability to initiate motion precisely was certainly compromised by these random movements of the aircraft. At times during this entire maneuver, especially trying to stop at the corners and to initiate movement after a relatively stable hover, I was overcontrolling on the cyclic stick. It was pretty sloppy flying until I got the aircraft under control and moving in the manner in which I preferred.

The ability to stabilize and hold preselected rates of movement was rather poor. Ability to stop precisely and come to a hover at the corners was in the ball park. I could certainly stop in the general area that I wanted, but ability to come precisely to a hover at the corners and to immediately enter a stable hover was certainly below average, leading to occasional overcontrolling maneuvers. Excessive attitude changes were not required. Ability to remain within ground-track limits was only fair. Control feel was good. Forces were not exceptionally high. Deflections were not any greater than normal. Because of the random movements I couldn't really trim the aircraft up to a hands-off position for any period of time.

In response of the aircraft to control inputs, the attitude changed pleasantly fast and pretty much to the pilot's desires. There was a fairly long delay between the time the aircraft changed attitude and the time that the aircraft built up a rate of movement consistent with the attitude change. Sensitivity of the aircraft in response to control inputs was close to ideal and ability to hold heading was good.

CASE 329 (RERUN) (Continued)

In the turns-over-the-spot, the ability to remain over the spot was compromised by the random movements and continual pilot workload to monitor attitude and make corrections to maintain position. There was a fair amount of control activity in order to maintain pitch and roll attitudes. There was no tendency for the aircraft to maintain a given setting. Ability to initiate turn rates was good. Ability to stabilize and hold preselected turn rates and stop on preselected headings, was good.

In the 90-degree turns in the wind, time to accomplish the maneuver was normal. There were minor overshoot and undershoot tendencies; again, I think that was due to the sloppiness of the control around the trim. Ability to establish heading and position over the spot generally was pretty good, but the precise stable hover after the maneuver was not very easy to establish or maintain.

Control activity was not excessive. Control power seemed adequate. Ability to establish and maintain a precision hover was compromised and degraded by constant attitude changes that came in randomly and by the pilot requirement to monitor and put in corrective control applications. The system was adequate for a vertical landing maneuver. Control activity wasn't wild in the cockpit but was still a little higher in terms of frequency than desired.

Quick stops could be accomplished as quickly as I desired. Excessive attitude changes were not required. Ability to hold the heading and altitude was quite good during the maneuver, and control motions seemed quite normal. Directional and height dynamics did not seem to affect the evaluation.

Overall Evaluation

The objectionable features were the random movement of the aircraft about a trim setting with continual pilot workload to monitor attitude and rates, and the requirement to add almost constant adjustments in the control system to maintain the situation that the pilot desired. Also there was a fairly long time delay between control input and aircraft response in terms of movement over the ground.

The favorable feature was the attitude response of the aircraft to control inputs. It was pleasantly responsive and predictable and I thought I had sufficient control to execute reasonably precise maneuvers, but they were not as precise as I would like to see in an ideal system. No particular piloting techniques were required.

CASE 330

$X_u = Y_v = -0.05$

$M_u g = -0.005$

$L_v g = 0$

$M_q = L_p = -2.000$

$M_\theta = L_\phi = 0$

$\lambda_{\theta_1} = -0.0307$ $\lambda_{\phi_1} = 0$

$\lambda_{\theta_2} = 2.000$ $\lambda_{\phi_2} = 2.000$

$\lambda_{\theta_3} = 0.0819$ $\lambda_{\phi_3} = 0.050$

PILOT D PR = A5 $M_\delta = 0.836$ $L_\delta = 1.154$

This particular configuration was fairly easy to fly but did require considerable attention from the pilot. Sensitivity setting was about a medium setting. The roll axis seemed fairly unstable and would drop off quite rapidly if no corrections were added.

Air-taxi-around-the-square - no problem initiating motion or holding a selected rate of movement. A little more difficult when going sideways because of the lack of stability. No problem coming to a hover and stopping at the corners. There was a tendency to overshoot a little bit going backwards and coming to a stop. Attitude changes were not excessive. Stayed fairly close to the ground track. Most difficult was tracking backwards. Control deflections were small throughout the maneuver. Response seemed satisfactory to control inputs in all axes.

Turns-over-the-spot - was able to stay over the spot very well. Attitude to control pitch and roll movements was satisfactory. No problem on turn rates or holding them or stopping on headings.

Crosswind turns - time was very short. The precision hovers following the turns were satisfactory, and control movements were very small while maintaining precise hover.

Quick stops - was able to stop very quickly, especially going into the wind, as expected. And going sideways with the wind - no particular problem coming to a stop there. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features - most objectionable was the lateral stability. Without careful attention it would drop off quite sharply in roll. However, it wasn't that difficult to fly.

CASE 330

$X_u = Y_v = -0.05$ $\lambda_{\theta_1} = -0.0307$ $\lambda_{\phi_1} = 0$

$M_u g = -0.005$ $\lambda_{\theta_2} = 2.000$ $\lambda_{\phi_2} = 2.000$

$L_v g = 0$ $\lambda_{\theta_3} = 0.0819$ $\lambda_{\phi_3} = 0.050$

$M_q = L_p = -2.000$

$M_\theta = L_\phi = 0$

PILOT D PR = A5 $M_\delta = 0.836$ $L_\delta = 1.154$

This particular configuration was fairly easy to fly but did require considerable attention from the pilot. Sensitivity setting was about a medium setting. The roll axis seemed fairly unstable and would drop off quite rapidly if no corrections were added.

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Turns-over-the-spot - was able to stay over the spot very well. Attitude to control pitch and roll movements was satisfactory. No problem on turn rates or holding them or stopping on headings.

Crosswind turns - time was very short. The precision hovers following the turns were satisfactory, and control movements were very small while maintaining precise hover.

Quick stops - was able to stop very quickly, especially going into the wind, as expected. And going sideways with the wind - no particular problem coming to a stop there. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features - most objectionable was the lateral stability. Without careful attention it would drop off quite sharply in roll. However, it wasn't that difficult to fly.

PILOT F PR = A3 M_δ = 0.838 L_δ = 0.866

This control system was characterized by a time delay between control input and when the vehicle attained its maximum rate of movement for that control input. It was also characterized by a fairly smooth response and by higher-than-normal and higher-than-desirable wind sensitivity. Control sensitivity, in order to give the vehicle reasonably quick response, was high.

In the air-taxi-around-the-square - the ability to initiate motion was reasonably normal. Ability to stabilize and hold preselected rates of movement was complicated by the effects of the wind upon the attitude of the aircraft, and it required considerable pilot attention and control movement in order to stabilize and hold a preselected rate of movement. Ability to stop precisely and come to a hover at the corners was again complicated by the wind effects upon the vehicle and the time delay between the time one put in control motion to stop the vehicle and the time the vehicle finally did come to a stop. I didn't consider the attitude changes due to wind excessive; however, they were higher than desired.

Ability to remain within ground-track limits was not too bad. Control feel was good. Forces were reasonable. At times, due to the characteristics of this control system, the pilot induced some attitude overcontrol into the stick, but the deflections were not out of the normal. Trimmability was good. In response to control inputs in pitch and roll, the aircraft was slow to build up to its final rate. Sensitivities were acceptable. Ability to hold headings with the rudders was pretty good; actually it was normal. Sometimes some of the attitude changes to compensate for wind effects did affect the ability to hold heading a little bit, but not to any serious degree.

In the turns-over-a-spot, the ability to remain over a spot was complicated by the sensitivity of the aircraft to wind effects. As I turned, the wind would start the vehicle drifting and it would take quite an attitude change in order to stop that movement and get back to the original spot. Therefore, the attitude control in pitch and roll was less than desirable in terms of the attitude required to compensate for the wind. Ability to initiate turns was acceptable. Ability to stabilize and hold a preselected turn rate was all right but at times when I started a turn the rate would be affected by the problem with pitch and roll control. Ability to stop on a preselected heading was again compromised sometimes by the problems that the pilot had with attitude control to compensate for wind effects in order to hold his position over the ground. Ninety-degree turns into the wind - time to accomplish this maneuver was not excessive although it was somewhat sluggish because of the time delay between the control input and vehicle response. Overshoot and undershoot tendencies were not degrading.

Ability to establish position and heading over a spot was pretty good. Control activity was not excessive. I think control power was adequate. In the precision hover maneuver, holding a very precise attitude required considerable pilot attention and considerable pilot activity with the stick. Although the control amplitude was small it did require frequent inputs to the controls. The aircraft did not remain in any given position. It was always falling off into one direction or another requiring considerable pilot attention to attitude control. A relatively precise hover could be maintained even with the wind effects, but it did require considerable pilot attention.

CASE 330 (Continued)

PILOT F PR = A3 $M_\delta = 0.838$ $L_\delta = 0.866$

This control system was characterized by a time delay between control input and when the vehicle attained its maximum rate of movement for that control input. It was also characterized by a fairly smooth response and by higher-than-normal and higher-than-desirable wind sensitivity. Control sensitivity, in order to give the vehicle reasonably quick response, was high.

In the air-taxi-around-the-square - the ability to initiate motion was reasonably normal. Ability to stabilize and hold preselected rates of movement was complicated by the effects of the wind upon the attitude of the aircraft, and it required considerable pilot attention and control movement in order to stabilize and hold a preselected rate of movement. Ability to stop precisely and come to a hover at the corners was again complicated by the wind effects upon the vehicle and the time delay between the time one put in control motion to stop the vehicle and the time the vehicle finally did come to a stop. I didn't consider the attitude changes due to wind excessive; however, they were higher than desired.

Ability to remain within ground-track limits was not too bad. Control feel was good. Forces were reasonable. At times, due to the characteristics of this control system, the pilot induced some attitude overcontrol into the stick, but the deflections were not out of the normal. Trimmability was good. In response to control inputs in pitch and roll, the aircraft was slow to build up to its final rate. Sensitivities were acceptable. Ability to hold headings with the rudders was pretty good; actually it was normal. Sometimes some of the attitude changes to compensate for wind effects did affect the ability to hold heading a little bit, but not to any serious degree.

In the turns-over-a-spot, the ability to remain over a spot was complicated by the sensitivity of the aircraft to wind effects. As I turned, the wind would start the vehicle drifting and it would take quite an attitude change in order to stop that movement and get back to the original spot. Therefore, the attitude control in pitch and roll was less than desirable in terms of the attitude required to compensate for the wind. Ability to initiate turns was acceptable. Ability to stabilize and hold a preselected turn rate was all right but at times when I started a turn the rate would be affected by the problem with pitch and roll control. Ability to stop on a preselected heading was again compromised sometimes by the problems that the pilot had with attitude control to compensate for wind effects in order to hold his position over the ground. Ninety-degree turns into the wind - time to accomplish this maneuver was not excessive although it was somewhat sluggish because of the time delay between the control input and vehicle response. Overshoot and undershoot tendencies were not degrading.

Ability to establish position and heading over a spot was pretty good. Control activity was not excessive. I think control power was adequate. In the precision hover maneuver, holding a very precise attitude required considerable pilot attention and considerable pilot activity with the stick. Although the control amplitude was small it did require frequent inputs to the controls. The aircraft did not remain in any given position. It was always falling off into one direction or another requiring considerable pilot attention to attitude control. A relatively precise hover could be maintained even with the wind effects, but it did require considerable pilot attention.

CASE 331

$X_u = Y_v = -0.05$	$\lambda_{\theta_1} = -0.0492$	$\lambda_{\phi_1} = 0$
$M_u g = -0.010$	$\lambda_{\theta_2} = 1.998$	$\lambda_{\phi_2} = 2.000$
$L_v g = 0$	$\lambda_{\theta_3} = 0.1017$	$\lambda_{\phi_3} = 0.050$
$M_q = L_p = -2.000$		
$M_\theta = L_\phi = 0$		

PILOT D PR = A5 $M_\delta = 0.696$ $L_\delta = 1.200$

In this particular configuration, roll seemed to be quite rapid; i.e., fairly high frequency, requiring frequent and rapid control inputs to maintain the position that was desired, especially in roll.

Air-taxi-around-the-square worked out pretty well with no problem in initiating the motion forward, sideways or backwards. Stabilizing on the speed presented no particular problem. Hovers at the corner worked out okay. Pitch and roll changes weren't excessive. Stayed fairly well within the ground track. There were a lot of quick stick inputs required to fly the machine at all times. Response seemed satisfactory in all axes.

Turns-over-the-spot presented no problems. Pitch and roll attitude control was satisfactory. Turn rate and so forth were satisfactory. Crosswind turns worked out pretty well; did not overshoot. There was a little lateral oscillation in the precision hover because of the bad rolloff in roll. Quick stops worked out okay. Directional and height dynamics were good.

Overall Evaluation

Objectionable features were that a lot of pilot activity was required to fly the machine. No particular comment on favorable features.

PILOT E PR = U7 $M_\delta = 0.908$ $L_\delta = 0.734$

I didn't like it. It was one of those models that I just didn't feel confident in. I felt I had to approach everything with a good deal of caution. I had considerable difficulty in the precision maneuvers with the roll control. In the gross maneuvers like quick stops, and in any large quick maneuvers in pitch attitude, I seemed to have problems. No comments on the control sensitivity.

The air-taxi-around-the-square - no complaints in getting moving. I had a good deal more difficulty than I'd like in controlling roll as I went around the square. Some problems with heading. Could not stop precisely - tended to overshoot. Fairly large

attitude changes required. Seemed to hang down on the nose into the wind more than I'd have liked. Could remain within the ground-track limits with effort but I was not satisfied with the performance.

Control deflections - no particular problem. There was a good deal of difficulty trimming, particularly in roll. Response to control inputs, I didn't like. There seemed to be a feeling that I was going to overcontrol in both pitch and roll. I was getting more attitude than I wanted.

Turn-over-the-spot - generally had difficulty with attitude control. Ninety-degree crosswind turns - didn't notice anything outstanding there. Precision hover - mainly had problems controlling the attitude as I went around, particularly in roll. Think I could land it. Control activity was more than normal.

Quick stops - tended to accelerate very rapidly. As a result I wanted to command a large change in attitude, but with the control response I was hesitant to do this and I tended to overshoot the spot. If I did put in rapid large attitude changes, particularly in pitch, I would lose control, hit the simulator stops and end up out of control. If I wanted to be precise about it, I had to use rapid large inputs, and I didn't like to do that with this model.

Overall Evaluation

Objectionable features - a general feeling that I could easily overcontrol and get into serious difficulty in both pitch and roll, particularly pitch in the gross maneuvers. Difficulty trimming, flying precisely in roll attitude. Special piloting techniques - I could fly it but I was very careful in the inputs and therefore not very precise in position control as I didn't have much confidence in it. Tended to very easily overcontrol, and potentially could lose control in both pitch and roll. There was a feeling that the vehicle was unstable. Mildly divergent oscillations resulted from small control input.

PILOT F   PR = A2-1/2 M_δ = 0.819 L_δ = 0.863

This was a very smooth and very maneuverable control system which gave the pilot a good degree of confidence in being able to maneuver the aircraft as he desired. One overall drawback was in a stabilized hover. It had a little bit of a looseness around the trim position and would not hold and trim into a good hover condition. It required constant pilot attention to maintain attitude and monitor small changes which seemed to occur randomly in the aircraft attitude. The pilot would have to correct these with control inputs in order to maintain his position over the ground in a hover.

Control sensitivity was selected medium high in order to give the aircraft the quickness in response to control inputs that this pilot preferred without becoming overly sensitive to inadvertent control inputs. Air-taxi-around-the-square and ability to initiate motion in each direction were reasonably good. The aircraft felt better while accelerating or while in an active maneuver than when trying to stop and stabilize into a fixed hover. However, the ability basically to initiate motion in each direction was good. I had a little difficulty in maintaining a preselected rate of movement due to

random variations to the attitude that seemed to be introduced. Whether it was due to the wind or whatever, it required pilot control input to attempt to maintain some preselected rate of movement.

Ability to stop at the corners precisely and come to the hover was good. No excessive attitude changes were required in pitch and roll. Ability to remain with the ground-track limits was probably above average. I felt I liked the control feel, especially during dynamic maneuvers. The force gradient was pleasant, deflections were excessive, and trimmability was normal. The control feel was one of the better combinations for a sense of control maneuverability. The response to control inputs was to this pilot's liking; pleasantly fast but not too fast. Sensitivity was reasonable - it didn't seem to be overly sensitive to control inputs.

Ability to hold heading was good. Turns-over-the-spot and ability to remain over the spot were complicated somewhat by random attitude changes that came in while attempting to maintain the spot. It required pilot workload in terms of interpretation of attitude changes and corrections through control inputs. Ability to initiate turn rate was good. Attitude control in pitch and roll was easily maintained although there was a constant workload in making minor adjustments. Ability to stabilize and hold preselected turn rates was good as was the ability to stop on preselected headings. Turns into the wind were easily accomplished with this control system. Very little overshoot and undershoot tendencies.

Ability to establish heading and position over the spot was very good. The real precision capability was modified by the continual pilot activity to hold a real precise hover. Control activity for this maneuver was normal especially if one could omit the small corrections needed to maintain the precision hover position. Adequacy of control power was normal. In fact, control power was fairly well-suited to this control system. Ability to establish and maintain position was very good in terms ot a rough hover position, but maintaining a real precise attitude or position over the ground required constant pilot attention and pilot inputs to the stick to correct random movements. It was very adequate for vertical landing.

Control activity was a little higher than average due to the random movement and inability to trim the aircraft up in a precision hover. Quick stops were accomplished as quickly as I preferred. No excessive attitude changes were required. Ability to hold heading and altitude was good and no excessive control motions were required except for the small additional workload to maintain the precision hover after the quick stop had been accomplished. Directional and height dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features were the random movements around a stabilized trim condition, particularly in a hover or a stabilized flight condition. Favorable features - it gave the pilot a very good degree of confidence in his ability to maneuver the aircraft as he preferred. It was a very good feeling control system in response to a pilot's desires. No special piloting techniques required.

CASE 332

$X_u = Y_v = -0.05$	$\lambda_{\theta_1} = -0.2273$	$\lambda_{\phi_1} = 0$
$M_u g = \quad = -0.140$	$\lambda_{\theta_2} = 1.963$	$\lambda_{\phi_2} = 2.000$
$L_v g = \quad = 0$	$\lambda_{\theta_3} = 0.3147$	$\lambda_{\phi_3} = 0.050$
$M_q = L_p = -2.000$		
$M_\theta = L_\phi = 0$		

PILOT D PR = A5 $M_\delta = 0.595$ $L_\delta = 1.100$

This particular configuration took considerable stick movement in both pitch and roll. Air-taxi-around-the-square - no particular problem initiating motion or stabilizing on the desired rate of movement. No problem stopping at the corners. Attitude changes weren't excessive. Stayed pretty well within the ground track. The control feel, forces, deflections and so forth, necessitated stirring the pot constantly to control the airplane and make it do what was desired. Response seemed satisfactory. Sensitivities - no comment.

Turns-over-the-spot worked out satisfactorily. Turn rates and so forth were okay. Crosswind turns - time was satisfactory. Undershot on the first turn, started slowing down a little too fast. No particular problem in precision hover. Here again, there was a lot of stick activity in hover. Quick stops - no problem. Directional and height dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features were that considerable pilot attention was required when flying with both longitudinal and lateral inputs. No comment on favorable features.

PILOT E PR = U8 $M_\delta = 0.794$ $L_\delta = 0.789$

This was a very surprising model. I had tentatively given it a low numerical rating until I lost control, which occurred not once but two or three times in the process of flying it. I allowed the velocity to build up to fairly high levels and then pushed over to stop, typically going backwards, and pushed over too far in attitude before I could check it. Then I hit the stops on the simulator and started to bounce back and forth and lost control. Before that, I was going to give it a much better rating but I did check it twice and it just got away from me twice. Otherwise the control response characteristics seemed good - it just went divergent in pitch.

CASE 332 (Continued)

Control sensitivities - no comment. Air-taxi-around-the-square - the ability to initiate motion seemed to require pretty large attitudes, but I could control the rate of movement and felt I could stop precisely and hover at the corners. Attitudes were large, but I didn't feel they were excessive. Ground track could be done. No problems with the control feel or forces. Response to control inputs initially felt very good to me. I could stop the attitude where I wanted it. Sensitivities were all right.

Turning-over-a-spot tended to be a little sloppy but no real problems. It was sloppy in position with the change in attitude required as I turned. Ninety-degree crosswind turns - no difficulties. Precision hover - I have mentioned. The quick stop was where I ran into problems. I didn't quite understand it but the pitch attitude just got away. So the model built up velocity very rapidly and if I let that get out of hand and then commanded large attitudes to arrest it, I got into trouble.

Overall Evaluation

I've outlined the objectionable features and the surprising divergence in pitch attitude. I would have to say it's controllable with difficulty since I'm not sure whether I would really lose control. However, once I hit the stops in the simulator, I had more difficulties than I would normally encounter in trying to fly the vehicle.

PILOT F   PR = A2-1/2 $M_\delta = 0.669$ $L_\delta = 0.713$

This was a fairly smooth and fairly maneuverable control system which had one drawback in that it was a little bit loose around the trim position of the control stick. In a hover I had to devote a fair amount of pilot attention to monitoring the attitude, and always had to be ready to counteract some random attitude changes that seemed to be introduced into the aircraft and degraded it a little bit. Otherwise, it seemed to be a fairly nice system.

Control sensitivity was just slightly above the average setting in order to give the aircraft reasonably fast response characteristics. Anything much higher would have introduced slight overcontrolling tendencies into the control stick. In air-taxi-around-the-square, altitude control on the initial part was poor; however, this was not due to the control system but to my inattention to altitude read-out and collective setting.

I thought the ability to initiate motion was slightly above average in this control system. I could pretty well stabilize and hold a preselected rate of movement. However, due to this looseness around the trim position, I had to be alert and put in control movements to maintain that rate when it was upset by the random motions. Ability to stop precisely and come to a hover at the corners was good. I did not feel that excessive attitude changes were required in pitch and roll. Ability to remain within the ground-track limits was good.

Control feel was good during maneuvers but I did not like the feel of looseness and the random movement around the trim position which I mentioned earlier. Forces were reasonable, deflections were tolerable. It was a little difficult to trim up

initially, but not bad. Response to control inputs in the pitch and roll axes was moderate, and sensitivities were about average.

Ability to hold heading was good. Turns-over-a-spot were good. Pitch and roll attitudes to counteract wind effects were about average. Ability to initiate turn rates, stabilize on preselected turn rates, and stop on preselected headings was good. In the turns into the wind, the time to accomplish the maneuver was not excessive. There were basically few overshoot or undershoot tendencies. Ability to establish the headings and position over the spot was very good.

Control activity did not seem excessive. Control power seemed adequate. Precision hover - I felt the initial hover was easy to establish and reasonably good to maintain except for the random attitude changes from the trim position which seemed to be introduced spasmodically. When encountered, they were relatively easy to correct. However, it did take a little bit of pilot workload to compensate for this. It was very adequate for a vertical landing.

Control activity was nominal for precision maneuver. Quick stops were performed as quickly as I preferred. Excessive attitude changes were not required. On the downward quick stop, I did overshoot my intended stopping point but it was not due to the control system. I think that had I repeated the maneuver, I could have stopped where I had intended in the first place. Ability to control heading and altitude was normal. Control motions were not excessive. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features were the random movement about the trim point, requiring pilot attention to attitude changes. Once the pilot did what he wanted, he could not divert his attention too long or the rate or stable hover would be disturbed and he'd have to make control inputs.

Favorable features - it was quite maneuverable and predictable, but not as solid feeling as I would prefer. No special piloting techniques were required.

CASE 332 (RERUN)

	$X_u = Y_v = -0.05$	$\lambda_{\theta_1} = -0.2273$	$\lambda_{\phi_1} = 0$
	$M_u g = -0.140$		
	$L_v g = 0$	$\lambda_{\theta_2} = 1.963$	$\lambda_{\phi_2} = 2.000$
	$M_q = L_p = -2.000$		
	$M_\theta = L_\phi = 0$	$\lambda_{\theta_3} = 0.3147$	$\lambda_{\phi_3} = 0.050$
PILOT E	PR = U7	$M_\delta = 0.813$	$L_\delta = 0.835$

This model seemed to be all right until all of a sudden I ran into problems in the gross maneuvers with overcontrolling. I got tangled up with stops, so I'm not sure whether I'd lose control in the real airplane or whether bouncing off the stops contributed to the problems. But it had a tendency to diverge in attitude with increasing velocity so it always wanted to fall over. When performing gross maneuvers like the quick stops, the primary problem was that the velocity built up very rapidly. Subsequently the rapid change in pitch attitude required to arrest the velocity meant putting in large rapid inputs; suddenly, there was gross overcontrolling and getting into trouble with stops.

The air-taxi-around-the-square - could initiate motion all right, but controlling it was a problem. It tended to get away both longitudinally and laterally. In stopping precisely in the square, one could do it with a little anticipation; but for the air-taxi task, the attitudes were quite large. Could remain within the ground-track limits easily.

No problems with the control feel or deflections. The response to control inputs in the hover was fast enough. The control response itself was satisfactory; but once moving, things started to get bothersome. Turning-over-a-spot didn't present any problems. No problems with trimming the wind out. Crosswind turns could be accomplished in a reasonable time. This wasn't the major source of complaint. Precision hover - external disturbances were not a factor. Could be landed and control activity was normal.

It was in the quick stops that the problems arose, so this model is derated within the gross maneuvers, not the precision ones. It was principally in pitch that I ran into the problem of velocity increasing more rapidly than I would have liked. Then trying to generate the large attitudes to stop the velocity led to overcontrolling and the feeling that it was divergent in pitch. The same rapid buildup of velocity was evident in roll, but for some reason I never ran into the problems of overcontrolling. Secondary dynamics -- not a problem.

Overall Evaluation

Objectionable features - rapid buildup in velocity - almost a divergence in velocity, coupled with a sort of speed instability; this led to having control difficulties and actually losing control. Whether one would lose control in the real case I don't know, because I hit the simulator stops in pitch several times in the quick stops. All this means is that a good deal of caution had to be used doing the quick stops. Therefore, I couldn't really do them and perform the mission the way I would have liked. It was controllable but unacceptable. There were deficiencies which required mandatory improvement and the performance was really inadequate when I started bouncing off the stops inadvertently all the time. But with a little caution I could do the job. It had major deficiencies which could lead to serious problems, so the performance was inadequate for the mission.

CASE 333

$X_u = Y_v$	$= -0.05$	λ_{θ_1}	$= -0.5975$	λ_{ϕ_1}	$= 0$
$M_u g$	$= -1.000$	λ_{θ_2}	$= 1.589$	λ_{ϕ_2}	$= 2.000$
$L_v g$	$= 0$	λ_{θ_3}	$= 1.058$	λ_{ϕ_3}	$= 0.050$
$M_q = L_p$	$= -2.000$				
$M_\theta = L_\phi$	$= 0$				

PILOT D PR = A6 $M_\delta = 0.886$ $L_\delta = 1.017$

This particular configuration seemed to have a great lack of stability, especially in the pitch axis. It seemed that if it were let go, it would drop off in pitch and lurch right away. Control sensitivity was a little higher than a medium setting because of lack of stability of this configuration.

Air-taxi-around-the-square - it was easy enough to initiate motion but a little difficult to hold it in the forward motion because of the lack of stability in the pitch axis. No particular problem in coming to a stop at the corners, and no excessive attitude changes in either pitch or roll were required throughout the square. Control feel forces - no comment. Deflections again were minimal. No comment on trim. Response seemed satisfactory to control inputs.

Turns-over-the-spot - could maintain fairly good position over the spot without excessive pitch and roll inputs. No difficulties in initiating the turn rate, holding the turn rate, or stopping on the preselected headings.

Crosswind turns - fairly rapid. Overshot the first stopping point. Hover was satisfactory as far as maintaining the position was concerned.

Quick stops - no problem here. Attitude changes were tolerable and there was no particular problem in coming to a stop either going forward or sideways. Secondary dynamics didn't have any effect on the evaluation.

Overall Evaluation

Objectionable features - the predominant one was the unstable pitch. Much more so than roll, although roll was felt to be unstable also. No particular favorable features.

PILOT E PR = U7 $M_\delta = 0.358$ $L_\delta = 0.339$

Pitch seemed to bother me most for two reasons. First, pitch input gave the impression of going right over on the nose; the rate of change of attitude seemed to be fairly large and even sort of divergent. And, second, there was a fairly large

attitude change with external disturbances for which large control inputs to compensate were required. I didn't like the spring gradient very much because I had to fight it a lot. Very difficult to trim.

The control sensitivities - no problems. The air-taxi-in-the-square - I had to concentrate very hard to try to keep anywhere near the line. Tended to wallow and roll going straight ahead. Had the same problem in selecting an attitude. Almost felt like it was getting away from me when I started to initiate a translation forward. Could initiate motion, but had to be a little careful that I didn't let it go too far.

Ability to stabilize and hold a prescribed rate of movement - found it very difficult in pitch. I think roll was reasonable. Didn't exhibit much precision in stopping or coming to hover in the corners. Was having difficulty. Very difficult to be precise. I think the attitude changes required at times, particularly in pitch, were excessive, and possibly coupled with the turbulence response. So I had difficulty remaining within the track limits. I had to concentrate fairly hard.

Control feel - wasn't too happy with the spring gradients since I seemed to be fighting them a lot. There was difficulty with the trim, particularly in pitch. The response in both axes seemed adequate to initial response but seemed to run away, particularly in pitch. Turn-over-the-spot - I had real difficulty remaining over a spot. Attitude control was particularly difficult in pitch. Turn rate - no problem. Ninety-degree crosswind turns - seemed to be able to do them reasonably well. Once again when coming to a stop, I seemed to have difficulties in controlling the pitch attitude.

Precision hover - I didn't feel that it was very precise and I thought I might have difficulty in landing. Quick stops - I could stop all right, but I was a little hesitant to use much control. Had the feeling it was going to get away from me if I did. So I didn't really think I used excessive attitude, but I think I was being a little cautious because of my lack of confidence in the system.

Heading and altitude - no problem. Control motions - seemed to be fairly large, particularly in pitch. Directional and height dynamics - no problems.

Overall Evaluation

The objectionable characteristics were predominantly in pitch. Seemed that the rate generated for a given stick input almost increased. There was a very unstable feeling with some oscillations, possibly due to external disturbances. Special piloting techniques - I think I was generally fairly cautious. I felt a deficiency, particularly in pitch, in that the feeling of an incipient loss of control was present.

PILOT F   PR = A4 $M_\delta = 0.727$ $L_\delta = 0.739$

In general, this was not a bad configuration to fly in terms of sensitivities. I selected pretty much of an average setting to strike a balance between the more predictable response and the ability to control aircraft attitude at the lower sensitivities where it was too sluggish, and at the higher sensitivities where it was too quick.

Air-taxi-around-the-square - this type of control system was a little difficult to get used to. Initially it tended to make me overcorrect and overcontrol until I dampened out the control inputs to fairly small values. Then I found that I could make the aircraft behave reasonably well. Ability to initiate motion was quite good. It was quick with the control sensitivity that I selected, but it was not very easy to maintain predetermined rates of movement. It took a lot of pilot attention again to maintain the correct attitude, and a lot of small inputs in the stick to maintain a desired attitude.

I could stop quite precisely on the corners and come to a hover. I did have a tendency to overshoot somewhat, especially in the downwind direction. So perhaps with pilot anticipation of wind effects, one would do better in coming to a precise hover over a predetermined spot. However, I couldn't pick out a precise spot and come to a hover over it, although I could come quite close to it.

Attitude changes were not bad for the square-tracking maneuver. Ability to remain within ground-track limits was fairly good. It took quite a bit of pilot attention and a lot of small inputs and precise monitoring of the aircraft attitude. So the workload was fairly high in order to make the aircraft do what I wanted. Control force, feel, and deflection were good. I was able to trim the stick up so I wasn't holding much force. The deflections were desirable. Ability to hold heading was good.

Turns-over-a-spot - at a low rate I had to work in order to compensate for the wind effects. I found that the last two 90-degree turns had rather large attitude changes in order to maintain an approximate position over the spot. This was due somewhat to the wind effects, I believe, and to overcontrolling from lack of pitch attitude reference in that one particular corner.

Ability to initiate turn rates with the rudder pedals was good. I could stop on a precise heading. There was a little bit of overshoot and undershoot tendency, but not bad. It did take work to anticipate stopping and holding a precise heading. The 90-degree turns into the wind worked out fairly well. I felt that I was able to come within the ball park on each corner quite easily, with minimal overshoot and undershoot tendencies. In those kinds of maneuvers I don't think I really was looking for real precise heading and position over the spot, but more or less for an area. For that purpose, it was quite adequate, as was the control power.

Precision hover - it took a lot of small inputs in the stick and a lot of pilot attention to attitude in order to maintain position. Again I had sort of a tendency of falling off the top of a ball. It required a lot of effort to maintain position. Control activity was fairly frequent but of small magnitude. I would consider it adequate for vertical landing but it would tend to make me overcontrol as I approached the ground, and the apparent motion became greater with these random movements. It would make for a less desirable vertical landing than optimum, although as far as safeness is concerned I think it would be adequate.

Quick stops - I had initial difficulties with controlling the altitude. Heading and coming to a stop over the spot were not bad. I didn't think that extreme attitudes were required. When I repeated it with a little more attention to the altitude and collective, the maneuver worked out quite well. The heading and altitude on

the second attempt worked out quite reasonably. Control motions were not large and I did not reach any wild attitude so I'd say that the whole maneuver was quite satisfactory. I didn't feel that the secondary dynamics (directional or height) had much of a control on the overall evaluation although I did have a problem with the initial quick stop.

Overall Evaluation

The objectionable feature was the demand upon the pilot to monitor pitch and roll attitude closely. It required many small inputs into the control stick in order to maintain attitude and therefore position over the ground.

Favorable features - it was quite quick reacting and it gave a good feeling for maneuvering. However, for precise hover stationary-type stable-moments, it was not a good flying machine. So, it was maneuverable but an unstable system.

Piloting techniques - I mentioned earlier that initially I had a tendency to over-control and, as I got used to the small pitch changes needed and the small inputs required, I could adapt fairly well to it and it at least became a flyable machine.

CASE 334

$X_u = Y_v = -0.20$ $\lambda = 0.3$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.91$

$M_q = L_p = -2.10$ $\zeta = 0.52$

$M_\theta = L_\phi = -3.84$ No wina, gusts, or stick forces

PILOT D PR = A4 $M_\delta = 0.800$ $L_\delta = 1.552$

This particular configuration seemed quite stable. There was one annoying feature in that it was necessary to constantly hold a back pressure on the stick. On the air-taxi-around-the-square, it was easy to initiate motion and easy to stabilize and hold the rate of movement desired, forward, sideways, and backwards.

Precise hovers worked out well at the corners. Pitch and roll attitude changes were not excessive. Stayed pretty well within the ground-track limits. Response to control inputs was good in all axes. Deflections were rather small. Had the sensitivity turned down quite a bit. Response was a little jerky in pitch.

Turns-over-the-spot worked out real well. No problem maintaining over the spot. Attitude control was very adequate in pitch and roll. Attitude changes were very small. No problem on the turn rate or holding the turn rate. Crosswind turns, time was not excessive. Didn't overshoot or undershoot. No problem coming to a stop at the corners.

Control activity was way down. Very adequate control power. Precision hovers worked out pretty well. Was able to stay pretty well over the spot. It seemed adequate for a vertical landing. Control activity was very small.

Quick stops forward were OK, and sideways worked out OK. No excessive attitude changes were required, and there was no problem on holding altitude. Control motions - not excessive at all, quite small control motions. Secondary dynamics, directional and height dynamics, did not affect the evaluation.

Overall Evaluation

The objectionable features were constantly having to hold back pressure on the control stick, plus jerky pitch changes. Favorable features - quite stable, easy to fly. Very little control motion requirea.

PILOT E PR = A3 $M_\delta = 0.883$ $L_\delta = 0.891$

This configuration was quite good. Only two things about it I didn't like: (1) velocities for a normal attitude were not sufficient, i.e., it didn't go fast enough for a given attitude change; and (2) I didn't really like the lack of centering in the stick,

i.e., it felt like a dead weight in my hand that was going to fall over at any time. So the ability to initiate motion was the one drawback.

I could stabilize motion at a preselected rate of movement and stop precisely. Attitude changes to get the desired velocity would be excessive. I could remain precisely within the ground track. The control feel, forces, and deflections were no problem except that the feel forces were missing. What I missed most, I think, was a lack of centering.

No real trim problems. Response to control inputs was good in both axes. Sensitivities were no problem. Headings were no problem. Turn-over-the-spot - no comments. Crosswind turns - once again, it took awhile because of the sluggish response in velocity. It took excessive time to accomplish the maneuver.

Control power was adequate and control activity was not a problem. Precision hover - no external disturbances. No problem with attitude or position. Could be landed. Control activity was normal.

Quick stops - couldn't get going fast enough, but could stop quickly enough. So for the speeds that I generated, the attitude changes were not excessive. They would be if I got going as fast as I wanted to.

Heading and altitude were no problem. Control motions - nothing outstanding there. Secondary dynamics were not of concern.

Overall Evaluation

One objection was the inability to generate velocity as quickly as I would have liked; or to state it another way, the attitude to generate the desirable velocity would be excessive. But I objected mostly to pitch although I think pitch and roll were about the same. Also, I didn't like the stick. I would like to have had some centering.

PILOT F   PR = A2 $M_\delta = 0.749$ $L_\delta = 0.766$

This was a smooth flying control system in terms of stick movements, the response of the vehicle in changing attitude, and command of control input. The one drawback in the system was that once the aircraft had assumed a particular attitude, it took a fair amount of time before the vehicle started to respond in performance to the change in attitude. In other words, change across the ground or stopping a rate of movement took time.

Control sensitivity was just slightly above the average setting I had been using here, and this was in order to give the aircraft smoothness of response. Anything much higher made the aircraft respond a little bit too quickly and sometimes abruptly to control inputs. If it was lower, the aircraft was just a little bit too slow in obtaining a correct attitude after I put a control input into the stick.

I thought the ability to initiate motion at predetermined rates was excellent, as long as the rate wanted was not too brisk or too fast. To initiate motion I did have to

wait a short period of time in order for the aircraft to respond. It would have been better if that response had been a little bit quicker.

Ability to stop precisely and come to a hover at the corners was outstanding, especially when considering the fairly slow rates that were attainable with this system. In other words, I couldn't get moving very fast; therefore it made the task a little easier in order to judge exactly where and when I was going to come to a stop. Excessive attitude changes were not required as long as I did not want a too energetic or brisk movement across the ground. I think if I wanted a fairly fast rate I would have had to attain quite an attitude and it would have been somewhat uncomfortable.

Ability to remain within the ground-track limits was excellent with the rates used here. This system had essentially a zero breakout force and zero force gradient, so it was a little bit different but not objectionable to this particular pilot. Stick deflections were not noticeable. In other words it was pretty much pressure application and I was not aware of any particularly large control deflections. This system could not be trimmed.

Response to control inputs was pleasantly fast, but aircraft response in terms of performance to control inputs was quite slow. There was quite a time lag there. Ability to hold heading throughout the maneuver was very good.

In the turns-over-the-spot, the ability to remain over the spot was excellent. This must be tempered with the fact that there was no wind; therefore, it should have been fairly easy. In this particular situation there was no workload at all to remain over the spot. Attitude control was not needed over the spot.

Ability to initiate turns, stabilize on preselected turn rates, and stop on preselected headings was excellent. In the 90-degree turns into the wind, the time to accomplish the maneuver was longer than normal but not excessive. I could initiate as fast a rate of movement as some pilots would like, but because of the slower rate of movement there was a slight tendency to undershoot the spot. I think this was only temporary; with a little experience with this system I would be able to accurately hit the spot nearly every time.

Ability to establish heading and position over the spot was excellent. Control activity was very minimal, and control power seemed adequate. Precision hover, once established, was a "piece of cake" so to speak. There was no stick activity and no disturbing moments requiring pilot attention or input. Excellent for vertical landing.

In the quick stops, I could not move quite as fast as I would have liked to from one position to another. Excessive attitudes were certainly not required, possibly due to the slow rates of movement across the ground. Ability to hold heading and altitude was excellent. Control motions were very minimal. Secondary dynamics did not enter into the evaluation.

Overall Evaluation

The objectionable feature was the slow aircraft response to control input, not the attitude change, but the movement of the aircraft across the ground in response to control inputs. Favorable features: extremely smooth, very pleasant to fly, predictable, and very easy to control the rate of movement. No special piloting techniques were required.

CASE 335

$X_u = Y_v$	$= -0.20$	λ	$= 0.30$
$M_u g = -L_v g$	$= 0.33$	ω_n	$= 1.82$
$M_q = L_p$	$= -0.30$	ζ	$= 0.06$
$M_\theta = L_\phi$	$= -3.30$	No wind, gusts, or stick forces	

PILOT D   PR = A4 $M_\delta = 0.712$ $L_\delta = 0.997$

This configuration seemed neutrally stable as far as dynamics were concerned in pitch and roll. There was a lack of damping and continuous oscillations of about the same amplitude in both axes.

In the air-taxi-around-the-square, forward motion was easy enough to initiate. There was a continuous pitch oscillation after the rate of movement was established. Not so much in roll. Going sideways, it did have a slight roll oscillation. Stops at the corners worked out OK. In the hover, again there was the slight pitch oscillation which was hard to damp out; it wasn't a great movement, but it was annoying.

It stayed within the ground track pretty well. Control deflections were very small. I had to hold back pressure constantly on the control stick. Response seemed quite good in all axes and sensitivities were satisfactory. Turns-over-the-spot - no problem remaining over the spot. Attitude control in pitch and roll was satisfactory.

Very small attitude changes were required and there was no problem on the turn rates. Crosswind turns - time was OK. It didn't overshoot or undershoot. Stayed fairly well on heading. Control activity was not great. Control power seemed adequate. Precision hover - was able to stay over the preselected spot in the hover; however, again there was a pitch oscillation and, every now and then, a slight roll oscillation. It would have been adequate for a vertical landing.

Quick stops worked out OK forward. Sideways in both directions - no particular problem. Control motions were not excessive. Not a whole lot of control activity. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features were the necessity to hold a constant back pressure, and the undamped pitch and roll dynamics. Probably the pitch oscillations were more noticeable than the roll, even though the lack of damping seemed the same, because of the constant aft pressure needed to be held on the stick. Favorable features - fairly easy to fly the particular mission.

CASE 335 (Continued)

PILOT E PR = A4 M_δ = 0.573 L_δ = 0.579

This configuration was reasonable to fly but had some minor deficiencies, principally in pitch. I was concerned with a small oscillation that resulted after each control input. It damped out fairly quickly but it was bothersome mostly in pitch. I tended to trigger this oscillation frequently. Also, the velocity for reasonable attitude was not sufficient in pitch.

The air-taxi – longitudinally, the ability to initiate motion was not optimum and it didn't seem to bother me in roll. Could stabilize and hold a preselected rate of movement. Could stop precisely enough and hover very nicely at the corners. The pitch attitudes to start and stop motions were large. Could remain well within the ground-track limits.

The control deflections were not noticeable. I'd still like to have had a little centering, but I wasn't overly bothered by that in this case. Response to control inputs – in pitch and roll, there was a tendency to trigger off an oscillation with each input. It damped out rapidly and was most bothersome in pitch. Doing the maneuvers I didn't seem to notice the oscillation in roll. Holding heading was not a problem.

Turning-over-the-spot was no problem. Ninety-degree crosswind turns – could accomplish the maneuver satisfactorily. Would like to have generated a little more velocity longitudinally, more quickly. Control activity was normal. Control power was not a problem. Could be very precise in hover, both in attitude and position. Certainly adequate to land. Control activity –no complaints.

The quick stops – longitudinally the attitude required to generate velocities was too large, as was the attitude change to stop. Coupled with the tendency to oscillate in pitch, rapid control inputs were required to stop the vehicle and usually ended up with some small oscillation which died out rapidly. Heading and altitude were not a problem. Control motions – most active in pitch.

Overall Evaluation

Although pitch was not very different from roll, when looking at the control responses in accomplishing the task, it was mostly in pitch that the deficiencies were noted. It was certainly controllable and acceptable; however, the combination of the oscillatory nature of the response, plus the large attitudes required to generate velocity, made it just less than satisfactory.

PILOT F PR = A2 $M_\delta = 0.700$ $L_\delta = 0.718$

This control system was very pleasant to fly. It felt very maneuverable in aircraft attitude changes and very responsive to pilot control input. The performance of the vehicle was not quite as responsive as desired and therefore it degraded the system a little, but the vehicle responded very pleasantly to control inputs and the pilot felt that he had a lot of control over the attitude of the aircraft. If the response had been a little bit faster performance-wise from attitude changes, this would have been an extremely ideal system.

Control sensitivity was medium high in order to quicken the change of attitude to control inputs without becoming too fast. Any lower sensitivity reduced the pilot's feeling of maneuverability with the system. This particular setting combined to make a very pleasant flying control system in terms of response to control inputs.

In the air-taxi-around-the-square, the ability to initiate motion was pretty good. I could very smoothly and precisely attain a certain attitude, but I would like to have seen a more snappy response in movement across the ground for a given attitude change. Ability to stabilize and hold preselected rates of movement was very good, as long as I was satisfied not to have a fast rate of movement. There was a little bit of pilot workload to maintain a given rate, but was not bad at all.

There was just a slight amount of random movement about any particular trim point. Ability to stop precisely and come to a hover at corners was good. It was enhanced by the fact that I couldn't get moving very fast; therefore, I had a little bit more time to judge what control input to make in order to stop where I wanted. Excessive attitude changes were not required for moderate rates of movement across the ground, although they would have been a little bit excessive if snappy rates of movement had been demanded.

Ability to remain within ground-track limits was very good. This was essentially a no-feel, no-force-breakout system. Deflections of the control stick were not extremely large. I was not aware of any large deflections during any of the maneuvers, and no trim was possible. Response to control inputs was very pleasant, predictable, and pleasantly fast as far as attitude changes were concerned in all of the maneuvers. It had a pleasant sensitivity to control inputs.

In the turns-over-a-spot, the ability to remain over a spot was very good which it should be since there was no wind. There was a very slight amount of random movement about the trim point to remain over the spot, but it was quite minor; therefore, attitude control was easy to maintain. Ability to initiate turn rates, stabilize and hold preselected turn rates, and stop on preselected headings, was very good.

In the 90-degree crosswind turns into the wind, the time to accomplish the maneuver was not real fast, but it wasn't excessive either. It would have been nice if I could have had a little bit faster rate of movement across the ground with moderate attitude changes. There were few overshoot or undershoot tendencies. Ability to establish heading and position over the spot was quite good. A small amount of work was required to maintain them, but not enough to make too much note of. Control activity was not excessive at all. Control power seemed plenty adequate.

CASE 335 (Continued)

Ability to establish and maintain a precision hover was basically good. There was a very slight amount of random motion requiring a little bit of pilot attention to attitude changes and corresponding stick inputs to correct them. It was very adequate for vertical landings, and control activity was nominal.

Quick stops - I could stop as quickly as I preferred because I couldn't move into the wind quite as fast as I would have preferred. Therefore, it didn't take as much attitude change to stop the lower rate of movement. Excessive attitude changes were not required. Ability to hold heading and altitude was good. No erratic or excessive control motions were required. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features – there was a small amount of random movement about the trim point in a precision hover, and the vehicle response was not as fast to attitude changes as preferred which somewhat limited forward air speed and movement across the ground. In other words, I had to trade off. If I had wanted a faster rate, I would have had to attain a more nose-low, wing-low attitude than would have been completely comfortable. Therefore, the pilot moderated his attitude changes and accepted a slower rate across the ground.

Favorable feature – it was a very nice combination of attitude change with control inputs, giving the pilot a very good feeling of control over the aircraft. No special piloting techniques were required.

CASE 336

$X_u = Y_v = -0.20$ $\lambda = 1.0$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.76$

$M_q = L_p = -1.80$ $\zeta = 0.67$

$M_\theta = L_\phi = -1.21$ No wind, gusts, or stick forces

PILOT D PR = A4 $M_\delta = 0.860$ $L_\delta = 0.938$

This particular configuration seemed fairly stable. Response seemed pretty good, both in pitch and roll. On the air-taxi-around-the-square - initiating motion, no problem occurred that needed correction. Was able to stabilize fairly well on the forward and backward motion. Sideways - the speed varied a little because of a 4-degree bank that was required to hold the rate of movement. Was able to stop pretty well at the corners and come to a hover. Pitch and roll attitude changes were not excessive. Very small changes. Stayed fairly well within the ground-track limits.

Control forces were fairly light. Deflections were very small. Was not able to trim and had to hold a constant back pressure on the control stick. Response seemed good in pitch and roll, also directionally. Sensitivity - no comment. Turns-over-the-spot - very little pitch or roll change and not much control motion was required. Turn rates were okay. Crosswind turns - time was okay. No overshoot or undershoot. Control activity was quite small.

Precision hover worked out pretty well. Stayed pretty well over the position. It was adequate for a vertical landing. Not much control activity at all. Quick stops worked out well going forward and sideways. No particular problem here. Control motions again were not excessive. Not much motion at all was required of the control stick to change the desired attitudes or to fly the vehicle as desired. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

The objectionable features were (1) not being able to trim the vehicle and (2) having to hold back pressure on the control stick at all times. Favorable features - stable, easy to fly. Was able to fly the mission very well.

PILOT E PR = A3 $M_\delta = 0.884$ $L_\delta = 0.891$

This configuration was quite pleasant to fly. The attitudes required to generate velocities seemed a bit large to me. I didn't like the stick without centering. The vehicle seemed to be a little bit oscillatory in pitch and roll. There was just a little bit of overshoot noticeable. It wasn't really bothersome. The control response characteristics were excellent. I could stop the motion just exactly where I wanted. No comments on the control sensitivities.

CASE 336 (Continued)

Initiating motion required too much attitude. Could stabilize and hold a preselected rate of movement and it was easy to stop and hover precisely. Excessive attitudes were required to generate velocities. I was more aware of this in pitch than in roll. Could do a good job on the ground track. Would like to have seen some centering. Deflections were no problem.

Control response - little bit of overshoot, but could find it only when I looked particularly for it. In the normal course of the maneuvers, the control response was good. Turn-over-the-spot was no problem. Crosswind turns were a bit slow. Couldn't generate the velocity that I wanted. Precision hover - there was no problem with external disturbances. Position was easy to maintain, adequate to land.

Control activity was normal. Could stop as quickly as I wanted to but couldn't get started as fast as I'd have liked. So excessive attitude changes were noticed mostly in pitch. Heading and altitude were no problem. Control motions didn't bother me. Secondary dynamics were not of concern.

Overall Evaluation

Objectionable features - large attitudes were required for generating a given velocity. Mostly noticeable in the quick stops in pitch. Didn't like the stick. Liked to have had some centering.

PILOT F PR = A3 $M_\delta = 0.862$ $L_\delta = 0.879$

This was a very smooth-flying, fairly maneuverable configuration. Even though there wasn't a trim position on the stick in the no-wind condition in which this was evaluated, there were constant random movements about the center positions; these movements required a fair amount of pilot attention to monitor the attitude and put in small control inputs to correct back to the desired attitude. This same characteristic made it difficult to stabilize on preselected rates of movement across the ground because of slight variations about the basic rate; this was due to the random movements of the aircraft about a particular trim condition.

Control sensitivity was selected medium high in order to give the aircraft a pleasant rate of response to control input; yet not so high as to cause an overly fast reaction of the control system, and a slightly rough ride. A lower sensitivity resulted in just too slow a response of the aircraft to control inputs. The system was characterized by a medium long time delay between aircraft attitude changes and a full rate of movement across the ground for the selected stick position.

In the taxi-around-the-square, the ability to initiate motion was fair in each direction. It was slightly degraded by the time delay between input to the stick and rate of movement across the ground. The ability to stabilize and hold preselected movement was not bad, but it was degraded somewhat by the constant random movement of the aircraft about a given trim position. Again this random movement caused a slight amount of over-control as I attempted to stop, slow down, and hover momentarily at the corners. It was not a precise maneuver due to the random movements of

the aircraft. Excessive changes were not required unless one wanted a very brisk pace across the ground.

Ability to remain within the ground-track limits I thought was quite good. Control feel--this was a no-breakout, no-force-gradient, and no-trimmability condition on the stick. Response to control inputs was pleasantly fast. The aircraft started to change attitude at a rate quite to this pilot's liking. So no complaints there. However, in the performance of the aircraft in response to attitude change, there was a fair amount of time delay.

Ability to hold heading was good. In the turns-over-the-spot, the ability to remain over the spot was complicated. There was more of a workload than I would like, due to the random movements of the aircraft. Control power seemed adequate. The ability to establish and maintain precision hover was a little below average. As far as the basic hover is concerned, it was easy to establish, but maintaining a real precise hover was degraded by the constant pilot workload to monitor precise attitude and make control changes or inputs in order to maintain the desired attitude. It was very adequate for vertical landing.

Control activity was slightly above normal due to the random movements of the aircraft and certainly above normal considering this was a no-wind evaluation. Quick stops were fast enough although one might like to see the ability to initiate a little bit faster movement across the ground without going to a steeper attitude. As long as one was content with moderate rates, the attitudes were not excessive. The greater the attitude change, the more difficult it was to hold precise altitude. Throughout the maneuvers, altitude control was a little bit more of a problem with this particular control system than with some others, although it was not an unreasonable workload for altitude control.

Control motions I didn't think were excessive. Directional and height dynamics did not seriously degrade the evaluation.

Overall Evaluation

Objectionable features - medium long time delay between aircraft attitude change and movement across the ground. I would like to have seen a little bit greater performance for a given attitude in terms of rates of movement across the ground. The random movements about any preselected trim position for a given maneuver were bothersome, requiring extra pilot monitoring for small attitude changes and control inputs to correct them. Overall, there was a slightly greater than normal workload for altitude control, although this was not serious.

Favorable features - it was a very smooth-reacting flight control system. I felt I could maneuver the aircraft quite confidently and make the aircraft perform within acceptable limits. I think wind would seriously degrade the system, and attaining a brisk movement across the ground would require a little bit larger attitude change than desired in an ideal system.

CASE 337

$X_u = Y_v = -0.20$ $\lambda = 1.0$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.61$

$M_q = L_p = -0.80$ $\zeta = 0$

$M_\theta = L_\phi = -0.21$ No winds, gusts, or stick forces

PILOT D PR = A4 $M_\delta = 0.830$ $L_\delta = 1.245$

This particular configuration seemed to diverge, both in pitch and roll. Wasn't a rapid divergence. In the air-taxi-around-the-square, on initiating motion, there was a slight tendency to overcontrol a little probably because of the lack of damping, when initiating forward, sideways, or backward motion. When holding the preselected rate of movement, there were slight pitch oscillations going forward and slight roll oscillations going sideways.

No particular problem coming to a hover at the corners. Pitch and roll attitude changes were very small. Stayed fairly well within the ground track. Control deflections were satisfactory. Not very large deflections. Had to hold a constant back pressure on the control stick. Response seemed satisfactory in all axes, and sensitivities seemed OK.

Turns-over-the-spot worked out real well. No problem on attitude control, and turn rates and so forth were satisfactory. Crosswind turns, time was okay. Didn't overshoot or undershoot. Able to stay fairly well in the position selected. Control activity and control power were satisfactory.

Precision hovers worked out real well; stayed over the spot. It would have been adequate for a vertical landing. Control activity again was not very large at all. Quick stops worked out real well, going both forward and sideways. Excessive attitude changes weren't required. Control motions, here again, weren't large at all. Secondary dynamics didn't affect the evaluation.

Overall Evaluation

Objectionable features were the divergence in pitch and roll; they weren't very noticeable but they caused an added control problem to the vehicle. The requirement to hold constant back pressure on the stick also was annoying. Favorable features — fairly easy to fly, and could complete the mission fairly easy.

CASE 337 (Continued)

PILOT E PR = A5-1/2 M_δ = 0.644 L_δ = 0.648

Could do the task quite adequately, but there were some bothersome characteristics. In pitch, slight inadvertent inputs would trigger off a rapidly divergent oscillation. In about one cycle the simulator was right on the stops. So with a little inattention, one could get into difficulties rather rapidly in pitch.

In the air-taxi-around-the-square, I didn't like the ability to initiate motion. Too much attitude was required in pitch. The velocity stabilized itself. In pitch, larger than desirable attitudes were required to stop. Didn't seem to bother me in roll. Could remain within the ground-track limits. The control feel – forces were not there, of course. Didn't really bother me too much. Not in proportion to the other things that bothered me, anyway.

The response to control inputs – no complaints about the roll. The initial response was quick in both axes; but in pitch, with any kind of disturbance, rapidly divergent oscillations were generated which were less than desirable. Sensitivities – no complaints. Turning-over-the-spot was not a problem. Crosswind turns could be accomplished. Once again, would have liked a little more velocity for the attitude than I got.

Precision hover – could be landed. Control activity – more active in pitch. Quick stops – could stop as quickly as I liked. A little more attention than normal was required in pitch, and the attitude changes were large. Heading, altitude, control motions – no comments. Secondary dynamics – no comments.

Overall Evaluation

The task could be performed adequately, but I felt there was a major problem in pitch in that a diversion of one's attention for any reason could lead to a rapid loss of control. Favorable features – in spite of the divergence in pitch, one could control the vehicle acceptably well; but it was unsatisfactory because of the pitch axis instability. As far as I could let it go, it seemed to be unstable. I think that the pitch axis was such that one could get into problems quickly, but certainly the task could be done quite well.

PILOT F PR = A2-1/2 M_δ = 0.717 L_δ = 0.735

This control system was a very responsive, pleasant, fairly confident-feeling system with regard to the pilot's ability to control and maneuver the aircraft. It was characterized by fairly frequent, low-amplitude random movements about a trim position, which complicated the hovering task and the maintaining of the rate of movement. Sensitivity was medium high in order to give pleasantly fast response to control inputs as far as attitude changes were concerned. Anything higher would give too quick a response, would sometimes lead to rough rides, and would produce a slight tendency to overcontrol. A lesser sensitivity resulted in too slow a response to control inputs with regard to attitude changes of the aircraft.

CASE 337 (Continued)

On air-taxi-around-the-square, the ability to initiate motion was quite good. I could stabilize and hold a preselected rate of movement pretty well, but it was modulated by random movements of the aircraft about a time position. Ability to stop precisely and come to a hover at the corners was quite good, very good in fact. Excessive attitude changes were not required. Ability to remain within ground-track limits was above average. This was a zero-breakout, essentially zero-force-gradient system. The deflections were moderate and desirable.

Response to control inputs was pleasantly fast, with good pilot ability to attain the proper attitude and maintain the rate desired. Ability to hold a heading during the tracking maneuver was good. Turns-over-the-spot, and ability to remain over the spot, were basically good. They were complicated and downgraded somewhat by the requirement to put in frequent small amplitude inputs in order to maintain a precise spot.

Ability to initiate turn rates, stabilize and hold preselected turn rates, and stop on preselected headings, was very good. In the 90-degree turns into the wind the time to accomplish the maneuver was not excessive, with minimal overshoot or undershoot tendencies. The ability to establish heading and position over the spot was good. It was somewhat degraded by this random movement. I could stabilize close to the spot pretty well but I couldn't be quite sure if I had the attitude that would hold the position or not, so I had to be alert as I established the hover to pick up changes and make corrections for it quickly. It gave the pilot a little bit of apprehension as to whether he really had the correct attitude he wanted for the condition.

Control activity was not excessive. Control power seemed very adequate. Precision hover — basically, establishing the hover was quite easy but maintaining a a precision hover required a fair amount of pilot attention to small attitude changes and small inputs into the stick to correct for the random attitude changes that seemed to occur without the pilot causing them. Since this was a no-wind condition, there was a higher workload than normal for an ideal system. Control activity was slightly greater than normal, but the whole maneuver was not a serious workload on the pilot.

Quick stops could be performed as quickly as desired. Excessive attitudes were not required. I felt that I could hit the spot fairly well. Ability to hold heading and altitude was good. Excessive control motions were not required. Directional and height dynamics did not seem to affect the evaluation.

Overall Evaluation

The most objectionable feature was the random movement about a desired attitude which occurred without intended control movements. This required constant pilot attention to monitoring attitudes and putting in small control inputs to maintain a desired attitude.

CASE 337 (Continued)

Favorable features — the aircraft responded to control inputs at a pleasant rate and predictable manner as far as attitude changes were concerned. The performance of the vehicle for a given attitude change was fair. It wasn't outstanding, but it wasn't bad either. It gave just the slightest sense of sluggishness to the response, but it was not seriously degrading. No special piloting techniques were required.

CASE 338

$X_u = Y_v = -0.20$ $\lambda = 0.30$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.91$

$M_q = L_p = -2.10$ $\zeta = 0.52$

$M_\theta = L_\phi = -3.84$

PILOT D PR = U7 $M_\delta = 2.628$ $L_\delta = 1.000$

In this particular configuration, the sensitivities were turned down to fly it best and make control a little easier.

The air-taxi-around-the-square - it was difficult to initiate forward motion because of the excessive attitude changes required. Here again, it was difficult to stabilize on the selected rate of movement because of the extreme nose-down attitude required which made it difficult to stop at corners and come to a hover. Sideways movement, no difficulty in initiating the motion. Here again it was a little difficult to maintain a preselected rate because of an extreme attitude change. There was a tendency to overshoot when coming to a halt, both sideways and forward, because of the excessive attitude changes required. All in all, it did make it difficult to stop at the corners.

Control feel - no comment, forces were satisfactory. Deflections were satisfactory; however, excessive attitude changes made it very unpleasant to fly. Vehicle response to a control input was unsatisfactory. No problem in holding headings. Turns-over-the-spot - here again the excessive pitch and roll made it very difficult to remain over the spot. Turn rate was satisfactory.

Crosswind turns - an increase in time was required because of the slow response of the vehicle to control input in achieving the movement of the vehicle. There was a tendency here to undershoot when turning into the wind. Precision hovers - once stabilized, I could hold position fairly well. Quite a bit of control activity. However, it was not excessive.

Quick stops - going forward into the wind, it was difficult to achieve much speed because of the excessive nose-down attitude required. Control motions - no comment there. Going sideways with the wind, quite a bit of overshooting occurred because of the attitude required. Secondary dynamics did not affect the evaluation.

Overall Evaluation

The main objectionable features were the excessive attitude changes required to fly the mission. No particular favorable features. It was controllable; however, the performance was definitely inadequate for the mission. The excessive attitude changes or attitudes required were unacceptable thus making this particular mission very difficult to fly.

CASE 338 (Continued)

PILOT E PR = U7 M_δ = 0.469 L_δ = 0.453

This model was extremely sluggish and required very large attitudes to counteract the wind. The result was that maneuvering required control displacements to keep the effects of the winds out to hold over a spot. The effects of gusts were mainly felt in the form of translation rather than attitude changes. No comments on the control sensitivities.

The air-taxi-around-the-square - the ability to initiate motion was very poor in either direction, and a large attitude was required. There seemed to be a significant time lag before the motion actually started. The attitudes required in pitch seemed to be more extreme than in roll. Maybe it was just that I didn't like looking down over the nose - felt like I was falling out of it. All of the maneuvers were, therefore, very sluggish and slow and there wasn't much precision. Excessive attitude changes were required.

Ability to remain on track didn't seem too bad, although the velocities were extremely slow because of the large attitudes required or because of reluctance to use the extreme attitudes that were required to get any kind of velocity. No complaints on the control forces except that when using large deflections, the force gradients were noticeable. The response seemed reasonable.

Sensitivities - ability to hold heading - no comments. Turn-over-the-spot - extremely difficult due to the large changes in attitude required turning out of wind to stay over the spot. Coupled with the gust response affecting position, it madé turning over a spot very difficult and little or no precision was achieved. The 90-degree crosswind turns didn't seem to stand out as a problem. Precision hovering has already been covered.

It was difficult to even get close to maintaining positional response. I think I could land the machine all right. Control activity - large displacements, but everything was happening very slowly so that there was no real problem with control activity. Quick stops - kind of a misnomer, because I couldn't get going very quickly. Excessive attitude changes were required to the point where the attitude to get any kind of velocity was too much to use. Heading and altitude - no problem. Secondary dynamics - no comments.

Overall Evaluation

The objectionable features - extreme attitudes required to trim out wind effects and large excursions in position due to gusts. Favorable features - really weren't any except everything was happening so slowly that control was no problem. Special pilot techniques - none. It was easily controllable, but not acceptable. Had major deficiencies in terms of maneuverability and precision hovering. The attitude changes required to trim out the wind effects were too large. The gust effects were large in the form of translation.

CASE 338 (Continued)

PILOT F PR = U7 $M_\delta = 0.855$ $L_\delta = 0.867$

This control system was smooth reacting, but it was characterized by the extreme attitudes required to counteract the wind effects and by extreme control displacements at the same time.

Control sensitivity was selected relatively high in order to give the vehicle sufficient control power to effect the attitude changes required to counteract the wind effects. Ability to air-taxi-around-the-square and initiate motion - when going into the wind, the ability to initiate motion at more than a slow rate was impaired because of the extreme attitude and low control power.

Ability to stabilize and hold a preselected rate of movement also was rather poor because of the considerable effect that slight wind changes had on control of the vehicle. Ability to stop precisely and come to a hover was not very good either. It wasn't too bad, actually, but it did require a little bit of lead and considerable attitude changes. The attitude changes in pitch and roll were excessive in order to accomplish the entire task of the whole rating program.

The ability to remain within the ground-track limits was fair, as long as I properly led the wind effects and allowed time to correct for them and get things stabilized and trimmed out. Then I could control the vehicle reasonably well on the ground-track limits. Stick deflections were quite extreme in order to attain the attitudes desired to make the vehicle respond.

Response to the control inputs in the lateral and pitch axis was quite slow. Ability to hold heading was good. The vehicle was extremely gust sensitive, as I previously mentioned. Ability to remain over a spot again was severely complicated by the reaction of the vehicle to the changing wind environment. Therefore, it resulted in extreme attitude-control problems. The aircraft did not actually tend to get away from the pilot, in terms of rapid movements. However, it did take a considerable period of time to initiate a turn, stop the drift, and then correct back to the original place over the ground. It was very difficult to anticipate what type of control action, reactions, and attitudes would be required to hold position over the ground.

The ability to stop on preselected headings was not too bad but I certainly did have a problem in stabilizing and holding a preselected turn rate due to the wind effects. In the 90-degree crosswind turns into the wind it was a fairly slow-reacting vehicle, at least at the control powers that I had selected. But the aircraft was controllable in attitude and was able to turn into the wind and hold a reasonable position over the ground with not too severe overshoot and undershoot tendencies.

The ability to establish a heading in a position was not too bad although if it drifted from the desired spot, it took time to correct and to get the aircraft to move back over the intended spot of hover. The control power was quite low. I'm not sure whether I would want to have it much higher though, because that would merely get the vehicle into more extreme attitudes in pitch and roll in order to counteract the wind. The ability to establish and maintain a precision hover, once stabilized, was not too bad. However, as I changed relative directions to the wind it did have a very adverse effect on the aircraft.

Quick stops - going into the wind, of course, I could not get up too high a rate of forward speed due to the extreme nose-down attitude required. However, holding the heading and altitude during the quick-stop maneuver was not too much of a problem. Control motions to initiate the attitude changes required were rather large.

Overall Evaluation

The objectionable feature was the extreme sensitivity to wind. Favorable feature - it was a smooth reacting control system.

Piloting techniques - large anticipation of the effect that the wind was going to have on the vehicle. At times I felt that I was about ready to run out of stick movement, and hit the stops before I was able to control a wind drift or attain an attitude which would give the mode of flight that I desired. In an operational situation of anything greater than 10 knots, one probably would run out of control and compromise the safety of the vehicle.

CASE 338 (RERUN)

X_u	= Y_v	= -0.20	λ	= 0.30
$M_u g$	= $-L_v g$	= 0.33	ω_n	= 1.91
M_q	= L_p	= -2.10	ζ	= 0.52
M_θ	= L_ϕ	= -3.84		

PILOT D PR = U7 M_δ = 0.854 L_δ = 1.171

This particular configuration was stable; however, the extreme attitudes required to fly it were extremely objectionable and uncomfortable. It made maneuvers much harder to accomplish.

In the air-taxi-around-the-square, an extreme nose-down attitude, which was quite uncomfortable, was required to initiate the motion. In sideways motion, too much bank was required. Because of the extreme attitude, it was difficult to hold the preselected rate. Stops at the corners weren't very precise, again because of the excessive pitch and roll attitudes required. Ground track was mediocre. Control feel, forces, and deflections - quite a bit of stick movement was required when flying. Response was a little sluggish in pitch and roll. When a quick response was needed, a large stick movement was required. There was a tendency to develop a PIO.

Turns-over-the-spot - here again, the pitch and roll requirements in changing position in relation to wind were very uncomfortable. Turn rates, etc. were satisfactory. In the crosswind turns, an excessive amount of maneuver time was required because the vehicle was unable to obtain much speed going across the square, and then when turning into the wind it almost stopped. There was an undershoot tendency. Control activity - an excess was needed. Precision hovers - here again, there was an uncomfortable attitude, quite a bit of nose-down tendency. Vertical landing would have been quite uncomfortable.

Quick stops - here again, going forward, a gross nose-down attitude was required to achieve forward motion. Stops worked out okay. Excessive attitude changes were required, both going sideways with the wind and out of the wind. There was a tendency going with the wind to overshoot because of the gross attitude needed to stop the vehicle. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features were the extreme attitudes in pitch and roll needed to control the vehicle and fly. Favorable features - it was stable.

CASE 339

$X_u = Y_v = -0.20$ $\lambda = 0.3$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.82$

$M_q = L_p = -0.30$ $\zeta = 0.06$

$M_\theta = L_\phi = -3.30$

PILOT D PR = U7 $M_\delta = 0.856$ $L_\delta = 1.116$

For this particular configuration, the control sensitivity was set at a medium setting. Generally, any maneuvers required an excessive attitude change or excessive attitude in maintaining a particular position in relation to the wind.

Air-taxi-around-the square - initiating forward motion was difficult. It was difficult to maintain the rate of movement. Coming to a stop at the corners - here again, going forward, it was hard to judge and hold a precise attitude to stop where desired. Pitch and roll attitude changes both were excessive. Stop sideways - there was a tendency to undershoot or overshoot, depending on whether the preplanning to stop was too early or too late. It was hard to judge just when to throw in a fairly steep roll or bank attitude to stop the vehicle.

Control feel and forces were OK, deflections satisfactory. Response to control inputs was satisfactory. Seemed to be an oscillatory tendency both in pitch and roll. However, frequency wasn't such that the pilot would cause a PIO.

In the turns-over-the-spot, it was difficult to maintain over the spot because of the excessive attitudes required, both in pitch and roll. Crosswind turns - maneuver time was excessive. However, it was possible to accomplish maneuvers. There was no undershoot or overshoot tendency here. However, turning into the wind it was real slow getting up to the point for the hover. Precision hovers worked out okay. In roll, most times, there was an oscillation when establishing a hover. Lateral oscillation there. It could have been satisfactory for a vertical landing; however, it would have been extremely uncomfortable with the sharp or steep nose-down and bank attitude required, depending upon the wind.

Quick stops going forward into the wind - couldn't get much speed out of it again because of the excessive nose-down attitude required. Sideways - required preplanning going with the wind. There was a need to roll in a bank to stop the movement quite a bit ahead of the point where it is desired to stop. Into the wind - no problem because the speed obtainable was quite low due to the excessive bank attitude required. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - extreme attitudes required to initiate and maintain movement, both forward and sideways, plus excessive attitudes required to hover into the wind. Also there was a slight oscillatory tendency in the roll and pitch. No favorable characteristics.

CASE 339 (Continued)

Special piloting techniques - it was necessary to preplan maneuver in relation to the wind because of excessive attitudes required. It was controllable but very uncomfortable to fly. It was inadequate for this particular mission.

PILOT E PR = U8 $M_\delta = 0.309$ $L_\delta = 0.273$

This configuration was terrible. The attitude to trim into the wind was very nearly the maximum attitude of the simulator. The forward translations were really inhibited by hitting the stops all the time. To move the machine into the wind required very extreme attitudes. No comments about the sensitivities.

To initiate motion was extremely difficult longitudinally into the wind. There was hardly any attitude left in the simulator to generate a velocity, so that flying the vehicle in any consistent manner was impossible. Also the attitude for a given stick input would quickly bleed off back to zero so that a rather complicated stick motion was required to maintain a selected attitude. For instance, laterally, a stick input immediately commanded an attitude in the correct direction. Then just about the time it was selected, it would bleed off to zero. So excessive attitude changes were required both in pitch and roll, particularly into the wind.

The same problem that existed in pitch into wind existed in roll when the wind was at the side. So with the extreme attitudes required, the forces became bothersome to hold. And the trim rate was such that for any kind of maneuver it was not adequate to trim out the forces fast enough.

When turning-over-the-spot, it was well nigh impossible to remain over the spot because of the extreme attitude changes as the vehicle turned in and out of the wind. The 90-degree crosswind turns - an excessive time was required to accomplish the maneuver and it certainly was not a continuous maneuver. The vehicle tended to undershoot. Precision hover was very difficult. Position was not possible to maintain. Attitude changes were too great to keep up with. Control activity was too much. Landing would be a marginal operation, particularly in any sort of gusty wind conditions.

Quick stop - couldn't really get the thing moving fast enough in the longitudinal direction to do any kind of a quick stop. Excessive attitude changes were present throughout. Directional and height dynamics - because of the concentration required to fly the machine, the height certainly was not very consistent. But that had nothing to do with the dynamics.

Overall Evaluation

Favorable features - none. Specific piloting techniques - no comments there. It was only because the problems were of a low-frequency nature that control could be maintained without getting into any PIO situations. It was controllable with difficulty, and required substantial pilot skill and attention to retain control and continue the mission. However, by paying attention, one could fly it and control it and avoid trouble because nothing happened very fast.

CASE 339 (Continued)

PILOT F PR = U7 M_δ = 0.734 L_δ = 0.777

This vehicle was supersensitive to wind effects and required extreme attitudes of the cockpit in order to counteract wind effects and to attain desired rates of movement across the ground. It required a high degree of pilot attention and workload in order to monitor attitude and make the aircraft perform as desired.

Control sensitivity was selected relatively high on the simulator in order to give the aircraft sufficient control power to counteract the effect of the wind. At times, moving into the wind, the simulator would bottom-out on the pitch limit and still I was just barely moving across the square. Any higher sensitivity than what I had created a control system that was a little bit too responsive, and led to more overcontrolling. The extreme attitude changes in order to change rates or change directions and compensate for the wind, introduced large control inputs. Often I overcontrolled and put in more of a correction or not quite enough. Stick activity was quite high. It was difficult to position the aircraft as precisely as the pilot desired.

In the taxi-around-the-square, the ability to initiate motion into the wind was limited by the attitude I could get with the control system; forward speed was quite limited. In the other directions, I had to use caution not to go too fast because of the extreme attitude required to slow down and stop whatever motion I had in a downwind direction. Ability to stabilize and hold preselected rates of movement was poor because of the constantly changing attitudes from wind effect. Ability to stop precisely and come to a hover at the corners was below average. Excessive attitude changes were required at times to stop a motion or to try to initiate a motion in a new direction.

Ability to remain within ground-track limits also was rather poor due to the frequent changes in attitude and the influence of the wind on the track of the aircraft over the ground. I felt the control feel was all right and forces were reasonable. Deflections at times became quite large in order to cause the aircraft to change the attitude to counteract the wind effects. Trimmability was adequate. The aircraft was reasonably responsive to the control inputs except that the aircraft performance was quite lacking in terms of control inputs. Unless I could get a large attitude into the wind, the aircraft did not respond in terms of the performance. It just didn't move across the ground like it should have, for the attitude it had. Ability to hold headings was good.

Turns-over-a-spot and ability to remain over a spot were poor due to the extreme attitude changes as the relative wind changed. Attitude control was quite difficult due to the large changes required. Ability to initiate turn rates was quite good. There was difficulty stabilizing on preselected turn rates because of the pilot workload in controlling the pitch and roll attitude. Ability to stop on preselected headings was compromised by the workload in the pitch and roll axes. In the 90-degree crosswind turns into the wind, the time to accomplish the maneuver was a little bit below what I would have liked, due to the low response to control inputs. I did have a tendency to overshoot or undershoot, not knowing exactly what the wind was going to do as I turned into the wind. Ability to establish heading and position over the spot wasn't bad but exact position was compromised by the poor response of the vehicle to control inputs. Control activity was frequent and control power was inadequate.

CASE 339 (Continued)

Ability to establish and maintain precision hover required a high degree of pilot concentration and workload due to the frequent and quite large attitude changes incurred by the gust factors. It was adequate for vertical landing but below average because in order to counteract the wind I had quite a nose-low, right-wing-low attitude. For vertical takeoff and landings it would be a rather poor system although probably safe enough with proper pilot technique.

Quick stops could not be performed as quickly as the pilot preferred. The movement into the wind across the square could not be initiated at a satisfactory rate. Excessive attitude changes were required. Ability to hold a heading and altitude was compromised somewhat by the workload for maintaining pitch and roll control. Control motions were quite excessive. Directional and height dynamics did not affect the evaluation of the pitch and roll, but quite the reverse; pitch and roll degraded the directional and height characteristics.

Overall Evaluation

Objectionable features were the extreme sensitivity of the aircraft to wind, the lack of performance from control inputs, and extreme attitudes of the aircraft in order to accomplish the various tasks. Favorable feature was a fairly smooth, fast-reacting control system; it wasn't jerky.

Special piloting technique - there wasn't really any except the extreme anticipation a pilot had to have for the wind effects on the aircraft and the attitude required in order to counteract these effects while performing certain maneuvers.

CASE 340

$X_u = Y_v = -0.20$ $\lambda = 1.0$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.76$

$M_q = L_p = -1.80$ $\zeta = 0.67$

$M_\theta = L_\phi = -1.21$

PILOT D PR = U7 $M_\delta = 0.887$ $L_\delta = 1.149$

This particular configuration was very undesirable to fly. Excessive attitudes both in pitch and roll were required. Control sensitivities were at medium setting and seemed satisfactory for response to fly this configuration.

Air-taxi-in-the-square - difficult to initiate forward motion and hold or stabilize on a movement. Actually came to a stop several times. Plus, it is uncomfortable going forward into the quartering crosswind because of the roll or bank angle required to maintain a track along the ground. Coming to a stop at the corners wasn't very precise because of the extreme attitudes required.

Attitude changes both in pitch and roll were excessive. This did make it difficult to stay within the ground-track limits going forwards or backwards. Excessive bank required made it difficult to hold the track. Going sideways, the excessive pitch changes to vary position forward or aft made it difficult to follow the track. Response to control inputs seemed satisfactory in all axes. However, the vehicle did not respond very rapidly to the inputs after a bank or a pitch attitude was established.

Turns-over-the-spot were unsatisfactory because it was difficult to stay within the area desired, due to the excessive pitch and roll changes relative to where the wind was. Turn rate and so forth were satisfactory. Crosswind turns - maneuver time was excessive because of lack of maneuverability. Unable to obtain the desired speed because of the excessive attitudes required. Control activity wasn't too great. It would be satisfactory as far as movement of the controls is concerned.

Precision hover - was able to establish and maintain hover. It was marginally satisfactory and there was a roll oscillation while in the hover. Control activity was not excessive. In the quick stops going forward into the wind, it was difficult to achieve much forward velocity at all because of the extreme nose-down attitude. Here again, excessive attitude changes were required. On the stop going forward, it was just a matter of taking off a little of the nose-down attitude to come to a halt. Sideways, it took preplanning when going with the wind in order to halt on the desired spot. Going into the wind, very little sideways motion was obtainable, thus making it easy to stop. Secondary dynamics didn't affect the evaluation.

Overall Evaluation

Objectionable features were that excessive attitude changes were required, both in pitch and roll, to initiate or maintain motion. When hovering over a particular point

to maintain position, the vehicle was required to be in an uncomfortable attitude at all times.

Favorable features - none. It was controllable, but the performance was inadequate for the mission.

PILOT E PR = U7 $M_\delta = 0.814$ $L_\delta = 0.835$

Not very comfortable to fly, mainly due to two deficiencies: (1) extremely large attitudes were required to trim out the wind effects and (2) there seemed to be a good deal of attitude response to external disturbances which was annoying in the precision maneuvers. In the gross maneuvers like the quick stops, the attitude limits of the simulator seemed to get in the way quite often so it was hard to judge how serious the deficiencies were at times. Tended to be operating very close to the pitch limits, for instance, into wind. For the lateral quick stops, the same thing was true. I didn't have much control left for maneuvering. I thought the attitudes were sufficiently extreme to make it unacceptable.

The sensitivities - no comments. Because of the limits of the simulator, the attitude remaining once I had the wind effect trimmed out, was not adequate to really move in the manner desirable. I tended to move very cautiously, especially forward in pitch. In general, there was difficulty in controlling roll attitude. Seemed to be bothered by disturbances there throughout.

The attitude changes - changes weren't excessive, but the steady-state attitudes were. I could remain within the ground-track limits with difficulty. There was a good deal of difficulty trimming when I moved in and out of the wind. Response to control inputs - there was a nice rate system in both axes. This wasn't the problem.

Turning-over-the-spot was a taxing problem. Ninety-degree turns in the wind tended to take a long time to accomplish. It tended to undershoot, possibly because of being overly cautious in pitch. It was near the simulator stops most of the time when coming around into the wind. The main problem in precision hover was controlling attitude because of the changing trim requirements and because of external disturbances, but I think it could be landed if a landing gear were provided on the nose.

Quick stops - could stop as quickly as I liked but I don't think I could go as fast as I wanted in the longitudinal case. Again, this was because of the simulator stops, combined with the extreme attitudes required to get rid of the wind.

PILOT F PR = U7 $M_\delta = 1.021$ $L_\delta = 1.064$

This control system was fairly smooth responding, but seriously lacking in performance and extremely wind-sensitive. With the attitude available from the simulator, sufficient ground speed could not be obtained to accomplish the maneuvers to the pilot's liking. At times, lack of response to the control inputs prevented the pilot from maintaining the aircraft within the acceptable performance limits for the task.

Control sensitivity was quite high in order to give a pleasant response time to the control inputs, and also to generate enough control power to make the aircraft perform as the pilot preferred. Going higher gave a little bit more control power but then it became oversensitive to control inputs and was not as smooth a ride or as pleasant a control system to fly.

In the air-taxi-around-the-square, the ability to initiate motion into the wind was marginal due to almost reaching the extremes of the attitude available; also, the aircraft just would not accelerate to a proper speed into the wind. And all of this was at quite extreme cockpit angles.

Ability to stabilize and hold preselected movements into the wind was almost impossible. It was easier when going downwind and I had a little bit more authority over performance. Ability to stop precisely and come to a hover at the corners was marginal. No problem into the wind because I could just barely get there. So it wasn't much of a problem to stop. However, going downwind I had a tendency to overshoot due to the speed buildup and due to the length of time it took in a rather extreme attitude to stop at some given rate. Excessive attitude changes were required to perform this maneuver.

Ability to remain within the ground-track limits was marginal. Control feel was all right, the forces were pleasant. Deflections, however, got quite large although they were acceptable. The control feel of the change of attitude due to control inputs was good; however, performance resulting from those inputs was quite lacking. Rates of movement across the ground due to attitude changes were very marginal. Sensitivities were reasonable. The aircraft seemed to respond reasonably quick to control inputs.

Ability to hold heading was good. Ability to remain over the spot was compromised by the extreme attitudes and inputs into the pitch and roll axes in order to maintain that spot. This was due to the extreme wind sensitivity of the aircraft. Ability to initiate turns, stabilize and hold preselected turn rates, and stop on preselected headings, was all right. However, these were all compromised somewhat by the sensitive characteristic of this aircraft to winds.

In the crosswind turns the time to accomplish the maneuver was somewhat excessive in that I could not attain a satisfactory speed across the ground, even crosswind, and also because of the extreme sensitivity to the wind. There was a definite undershoot-overshoot tendency. Ability to establish heading and position over the spot was reasonable. Control activity due to having to compensate for attitude changes was considerably above normal, and control power was lacking.

Ability to establish and maintain precision hover was fair. It was not easy to do because of the considerable attitude changes required to compensate for the wind and maintain position over the ground; however, once established it was not too difficult to maintain. It was marginally adequate for vertical landing because of the extreme right-wing, nose-low attitude required to hold the position over the ground. This required an abnormal touchdown attitude and, therefore, it would require special piloting technique to perform this maneuver. In more gusty wind conditions or stronger wind conditions, this would be a very hazardous maneuver.

CASE 340 (Continued)

Control activity - there were odd-ball displacements of the controls, but once I had them set up, the activity was not too much greater than normal in order to maintain a hover attitude. Quick stops could not be performed as quickly as desirable due to limited performance into the wind. Excessive attitude changes were required in order to initiate movement into the wind. Ability to hold heading and altitude was not bad. Control motions required going downwind were quite large and again were due to the susceptibility to wind effects. Directional and height dynamics did not seem to enter into this evaluation.

Overall Evaluation

Objectionable features were the extreme sensitivity to wind, large control displacements in order to attain rates and movements, and the extreme attitudes of the aircraft in order to maneuver. A favorable feature was the fairly smooth reacting system, but it was lacking certainly in control power. There was a nice feel to the control system and to the initial attitude response; however, performance was lacking. No special piloting techniques were required other than extreme anticipation of wind effects.

<u>CASE 341</u>

$X_u = Y_v = -0.20$ $\lambda = 1.0$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.61$

$M_q = L_p = -0.80$ $\zeta = 0$

$M_\theta = L_\phi = -0.21$

<u>PILOT D</u> PR = U7 $M_\delta = 0.674$ $L_\delta = 0.952$

In general, this was a very uncomfortable vehicle to fly because of excessive attitudes required for movement of the vehicle both forward and sideways.

Air-taxi-around-the-square - it was difficult to initiate forward motion, and then difficult to stabilize or hold the preselected rate of movement. Here, it was uncomfortable because of excessive nose-down attitude plus going forward with the quartering crosswind. Bank attitude into the wind also was required. It was difficult to precisely stop and come to a hover at the corners, again because of the excessive attitude changes.

In staying within the ground track, going forward was no problem. Going sideways was difficult because of the nose-down attitude of the aircraft and the attitude changes required to stay on a path going sideways. Control deflections were satisfactory. Response to control inputs was okay in all axes.

In the turns-over-the-spot, it was difficult to remain over the spot because of the change in position or velocity of the wind. Excessive pitch and roll attitude changes were required. There was no particular difficulty in initiating turn rates or stabilizing on the turn rate. Crosswind turn - excessive time was required here. Going crosswise to the wind was uncomfortable because of the bank attitude necessary to maintain a track across the ground. There was no undershoot or overshoot tendency, but the time to accomplish maneuver was quite excessive.

Hovering over a spot was marginally satisfactory. It took a while to get stabilized exactly where desired. Quick stops - forward motion in the wind was very slow, requiring a minor attitude adjustment to come to a stop. Going sideways with the wind there was a big tendency to overshoot, and again the roll attitude required to stop movement over the ground was excessive. Control motions were okay. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features were the excessive attitude changes required to initiate and maintain motion of the vehicle both forward and sideways. No favorable features. It was controllable, but the performance was inadequate for the mission because of the excessive attitude changes which were uncomfortable for the pilot to fly.

CASE 341 (Continued)

PILOT E PR = 10 $M_\delta = 0.466$ $L_\delta = 0.501$

The thing was terrible. I had to use a pitch attitude in the wind that was very close to the stops so that the available control power forward was very limited. It had a really rapid oscillatory divergence such that I didn't want to turn the sensitivities up any higher than I had them. I felt at best that at times I was marginally in control. I did lose control coming out of the hovering turn. I had to select an extreme nose-down pitch attitude to trim into wind and then slightly overcontrolled and bounced into the stops several times. So the combination of the extreme attitudes required to trim the wind, plus the fairly rapid oscillatory divergence which I particularly noticed in pitch, made the model uncontrollable from my point of view. And uncontrollable means that control will be lost sometimes during some portion of the mission, and that was clearly what happened.

I managed to complete the air taxi without too much difficulty by crawling very slowly along. The ability to initiate motion was very poor, and the precision on the corners I don't think is worth commenting on. I was sliding around somewhat and felt as if I was just about ready to fall out of the cab. Excessive attitudes were very evident in pitch. The heading, control feel, and sensitivity problems were outlined initially.

Turn-over-the-spot was fairly controllable because of the large attitude changes required as I turned in and out of wind. And that's where the mission ended, because I lost control.

PILOT F PR = U7 $M_\delta = 0.617$ $L_\delta = 0.429$

This control system was extremely wind-sensitive and the control power or response of the vehicle to the stick inputs at times was not completely adequate to compensate for the wind effects. Control sensitivities were set at a moderately high setting to help the vehicle respond to the wind effects by increasing the control power. In order to make the vehicle respond reasonably fast to the control system inputs, it was set slightly higher in sensitivity than the average.

In the air-taxi-around-the-square, the ability to initiate motion into the wind was very marginal. I could not initiate a satisfactory rate and the ability to alter that rate was very marginal with this control system. Ability to stop precisely and come to a hover at corners was poor due to the wind effects. I did not know exactly how long it was going to take the vehicle to stop from the control input; and if the wind changed slightly, this would alter the pilot's ability to control the aircraft precisely.

Attitude changes were larger than average in order to compensate for the wind effects, and at times gave the pilot a rather uncomfortable feeling of being pitched over into a bank or pitch attitude in order to compensate for the wind effects. Ability to remain within ground-track requirements was quite marginal, especially when the wind would make the vehicle respond.

Control feel was good. The vehicle responded smoothly to the control inputs. Forces were not excessive, deflections were slightly greater than average, and trimmability was okay. Response to control inputs about the pitch and roll axes was

basically smooth and desirable; however, the end results with regard to the vehicle's control were not too good.

Sensitivities were okay. Ability to hold heading was complicated by the wind effects but it was all right. Turns-over-a-spot and ability to remain over a spot were compromised by the wind effects. Attitude control in pitch and roll was quite excessive again due to the wind effects. Ability to initiate turn rates was okay. To stabilize and hold preselected turn rates with the rudder control was adequate; however, cyclic inputs were quite high in order to attempt to hold position over the ground during the turns. Ability to stop on preselected headings was all right.

In the 90-degree crosswind turns, times were slightly excessive, but this looked better than the vehicle really was because I was only going crosswind. I did have undershoot tendencies because the vehicle came to a stop a little faster than I thought with turning into the wind. Again this was because the vehicle was affected so quickly by the wind as I changed heading.

Ability to establish heading and position over a spot was only marginal because of the limited control the pilot had over the vehicle. Control activity was relatively high and adequacy of control power was inadequate at times, especially during maneuvers into the wind. Ability to establish and maintain a hover was quite marginal due to excessive wind effects. I did consider it adequate for a vertical landing. If I could have figured out what the wind was doing, and anticipated that properly, I wouldn't have overcontrolled. However, unless one was very alert to catching wind effects there was excessive movement and excessive time to stop the movement and this did lead to an excessive use of the cyclic stick.

Quick stops could not be performed as quickly as desired. I could initiate the movement into the wind at a comfortable rate but there was excessive stick displacement. The vehicle hit the stops and then bounded back in the opposite direction. Excessive attitudes were required. Ability to hold heading and altitude was compromised by the other difficulties in performing the quick stops. Control motions at times became erratic due to hitting limit stops. I did have difficulty with directional and height control because of the effects of the wind on the vehicle.

Overall Evaluation

Objectionable features were certainly the sensitivity of the vehicle to wind effects, the inadequate control power to make the vehicle perform as the pilot wanted it to, and the inability to hold precise hovers and predetermined rates. Favorable feature - it was a fairly smooth vehicle in response to control input, but that was certainly outweighed by the other objectionable features. Special piloting techniques - none particularly, other than a great appreciation and anticipation of what the wind was going to do to the vehicle.

CASE 342

$X_u = Y_v = -0.20$	$\lambda = 0.30$
$M_u g = -L_v g = 0.33$	$\omega_n = 1.91$
$M_q = L_p = -2.10$	$\zeta = 0.52$
$M_\theta = L_\phi = -3.84$	No wind or gusts

PILOT D PR = A3 $M_\delta = 0.830$ $L_\delta = 0.922$

This particular configuration appeared very stable. The control sensitivity was turned up to get the response desired, and it seemed that by doing this the stick was a little bit too sensitive around the neutral point.

Air-taxi-around-the-square - real easy to initiate motion, both forward and sideways, and hold a preselected rate of movement. Easy to come to a stop at the corners. Attitude changes were not excessive. No problem remaining within the ground-track limits.

Control feel, forces, and deflections - to get the response desired the sensitivity was turned up and it was just a little too sensitive, mainly in the pitch axis. Very minor control inputs were required to fly the airplane. Turns-over-the-spot - no problem here. It could almost be flown "hands off." Crosswind turns - time was not excessive. No overshoot or undershoot.

Coming to a precision hover - very easy. Extremely stable machine. It would have been adequate for a vertical landing. Very little control activity.

Quick stops - no problem coming to a stop. Attitude changes were not excessive and it was easy to hold heading and altitude. Very minor control motions. Once it was in trim, the pilot could let go of the stick and hold the hover pretty well. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - no comments here. Favorable features - extremely stable, easy to fly.

PILOT E PR = A2-1/2 $M_\delta = 0.893$ $L_\delta = 0.900$

I liked it. No comments on the sensitivities. The only problem I found was that the ability to initiate motion was less than optimum, but the velocity stabilized and I could hold a preselected rate easily. I could stop very quickly and precisely, and hover easily at the corners. The attitude changes were large. I couldn't get enough velocity for the attitude change that I wanted to use to initiate the motion. I could do an excellent job on the ground track, as good as I wanted.

CASE 342 (Continued)

No complaints about feel, forces, deflections, or trim. Response was good in both axes. Sensitivities - no comments. Turn-over-the-spot was very easy to perform accurately. Ninety-degree crosswind turns - the same small complaint about velocities. I couldn't get up to speed fast enough for my liking.

Precision hover - no problem with attitude or holding position. Control activity was moderate; no complaints there. Quick stops - I could stop as quickly as I wanted, but large attitude changes were required to establish the velocity. Heading, altitude - no problem. Control motions - no complaints.

Overall Evaluation

The objectionable features were the large attitudes required to generate velocities. That's really a minor complaint. It was well-behaved. The favorable features were that it was pleasant to fly, no turbulence, and good response in both pitch and roll. I should comment here that the complaint about attitudes to generate velocities is really only for the pitch axis. It didn't bother me as much laterally. It was certainly controllable, acceptable, and satisfactory, and it qualified as good, pleasant, and well-behaved.

PILOT F   PR = A2 M_δ = 0.694 L_δ = 0.711

This was an extremely smooth, very predictable flight control system degraded to a very minor part only by its lack of easy maneuverability. It wasn't quite as quick responding and as maneuverable as some pilots might like to see.

Control sensitivity - the initial run was made with a medium low sensitivity selection and this made the vehicle even less responsive to control inputs. However, the precision with which the aircraft could be maneuvered was outstanding. I reran it with a higher sensitivity which increased the maneuverability to a more desirable level and still retained the precision of maneuvering the aircraft.

In the air-taxi-around-the-square, I thought the ability to initiate motion in each direction was excellent except that I could not attain a real fast rate of movement across the ground. I didn't want to go too much steeper in attitude in order to attain a faster rate of movement across the ground; therefore, I was forced to accept a slow rate. Ability to stabilize and hold a preselected rate of movement within that available, was excellent. Ability to stop precisely and come to a hover at the corners also was excellent.

Excessive attitude changes were not required in the sense that if I wanted to go faster I would have had to go to somewhat of an excessive attitude. However, I think most pilots would be content to accept a moderate attitude change at a slower rate of movement. Ability to remain within the ground-track limits was excellent. Control feel, forces, deflections, and trimmability all were very good.

Response to control inputs was pleasant. The attitude change was pleasantly fast to control inputs; however, movement across the ground was not as great. The

performance for the aircraft with attitude change was not quite as strong as preferred. Sensitivities - no problem there with regard to oversensitivity to control inputs. Ability to hold heading also was outstanding.

Ability to turn-over-a-spot certainly was enhanced by the fact that this was a no-wind evaluation, and ability to remain over the spot was excellent. Attitude control - as far as the pilot was aware, there were no control stick inputs in order to maintain position while initiating and stopping turns. Ability to initiate turn rates, stabilize on a predetermined turn rate, and stop on preselected headings, was outstanding.

Ninety-degree turns into the winds weren't as snappy as I would have liked with regard to movement across the square to approach the hover spot. However, there were little overshoot or undershoot tendencies in accomplishing the maneuver. Ability to establish heading and position over the spot was very good. Control activity was very, very minimum.

Control power - it seemed adequate in terms of being able to attain attitudes of the aircraft which were comfortable to the pilot. However, as mentioned earlier, the performance of the aircraft left a little to be desired. Ability to establish and maintain precision hover was outstanding. Once stabilized, and it was easy to stabilize, there was no pilot workload whatsoever. It was completely adequate and excellent for a vertical landing. Control activity was very minimal.

In the quick stops, I could not initiate the rate of movement into the wind or into the preselected stopping area as quickly as I would have liked. Excessive attitude changes in order to attain a rapid rate of movement would have been required. However, initiating a reasonable rate, not as fast as desired perhaps but still reasonable, did not require excessive attitude changes nor were they required to stop the maneuver. Ability to hold heading and altitude was very good.

I think that if a person were to use the steeper attitudes and faster rates, altitude control probably would be affected. Control motions required were predictable and easily accomplished. Directional and height dynamics did not seem to affect the evaluation. I think if a pilot demanded the faster rates of movement across the ground, this would then require greater attitude changes; I believe then the greater attitude changes would introduce height control problems, at least in additional workload. As it was, with the control sensitivity that I selected on the second run, height control was not a problem anymore than it normally was.

Overall Evaluation

The objectionable feature would be that the aircraft was not sufficiently responsive in terms of performance, compared to attitude changes required to initiate a rate of movement across the ground. I would like to have seen greater performance from a given control input.

The favorable feature was that the aircraft was extremely smooth and very predictable, while lacking in complete maneuverability. In terms of movement across the ground it gave the pilot a very confident feeling in attaining attitudes and making the aircraft perform in terms of attitude control. No special techniques were required.

CASE 343

$X_u = Y_v$	$= -0.20$		λ	$= 0.3$
$M_u g = -L_v g$	$= 0.33$		ω_n	$= 1.82$
$M_q = L_p$	$= -0.30$		ζ	$= 0.06$
$M_\theta = L_\phi$	$= -3.30$		No wind or gusts	

PILOT D   PR = A3 $M_\delta = 0.619$ $L_\delta = 0.709$

This particular configuration was fairly easy to fly and appeared very stable. It was slightly damped both in roll and pitch.

Air-taxi-around-the-square - no problem initiating motion or stabilizing on the rate of movement. Easy to come to a hover at the corners. Pitch and roll attitude changes were satisfactory.

No difficulty remaining within the ground-track limits. Control feel, forces and deflections were all satisfactory. There was a slight oscillation in pitch because of the light damping. Response to control inputs - there was a slight tendency to cause an oscillation longitudinally.

Turns-over-the-spot - no particular problem here. Slight pitch oscillations. Laterally, it was lightly damped. No noticeable oscillatory tendencies in that axis. No particular problem on turn rate, stabilizing on a selected turn rate, or stopping at the headings.

Crosswinds turn time was satisfactory with no overshoot or undershoot tendencies. Precision hovers worked out quite well, again maybe a slight pitch oscillation. Adequate for a vertical landing.

Quick stop - no problem here. Secondary dynamics, directional and height dynamics were good.

Overall Evaluation

Objectionable features - the only one really was the oscillatory tendency in pitch or the light damping in pitch and roll. The pitch oscillation was annoying. Favorable features - very stable, easy to fly.

PILOT E   PR = A4-1/2 $M_\delta = 0.258$ $L_\delta = 0.293$

The vehicle was oscillatory in both pitch and roll. When I tried to select a constant attitude, there was always a small oscillation about the steady state. The response was such that this oscillation could easily be damped out by the pilot. So it was more of an annoyance than being really bothersome to the performance. Also the

attitudes required to generate velocities were too large, particularly in pitch. Or stated another way, the velocities for the attitude that I wanted were too small.

Air-taxi-around-the-square - ability to initiate motion was no problem except that the attitude tended to be more than I liked. Preselected rate of movement was easily attained. Precision hover was no problem. In spite of the oscillatory nature in pitch and roll, the pilot could stop the oscillation at will.

No problem remaining on the ground track. The control feel and the forces to hold a constant translational rate were a little bothersome. Response to control inputs was good. I could stop the oscillation at any time.

Sensitivities - I thought perhaps I selected them a little bit low after I flew the task. The turn-over-the-spot was very good - no problems. Ninety-degree cross-wind turns - no real comments. Precision hover was good.

Quick stops - could certainly stop as quickly as I wanted but, when initiating the motion, the attitudes were a little large. Heading and altitude - I don't think they were problems. Secondary dynamics - not of concern.

Overall Evaluation

Objectionable features - oscillation in pitch and roll about a steady-state attitude. Favorable features - certainly no effects from external disturbances. In spite of the oscillations, the pilot could control the vehicle as desired. Special piloting techniques - none required.

PILOT F PR = A2 M_δ = 0.575 L_δ = 0.480

This evaluation was conducted in a no-wind situation. The control system was a very responsive system but quite sensitive. The control sensitivity was at a medium setting in order to give the vehicle proper quickness of response, balanced against the oversensitivity of the vehicle to small stick inputs on the other end of the spectrum. Generally, very small stick movements were required in flying the vehicle. Of course, there were no wind effects to counteract, but it did require a fair amount of pilot attention to maintain a level attitude. If I put in a little bit of a stick input, the vehicle did have a quick response and then I'd have to put in a counteracting control movement to maintain the attitude; this created the sense overall of precariously balancing on top of a ball.

In the air-taxi-around-the-square, ability to initiate motion was good. Just a very small input would give a fair increase in rate, attitude, and rate of movement across the ground. So the entire system was characterized by a fairly high degree of sensitivity. I was able to stabilize and hold preselected rates of movement quite well. Ability to stop precisely and come to a hover at the corners was good. This was helped considerably by the no-wind condition.

CASE 343 (Continued)

Excessive attitude changes were not required; although considering the no-wind condition, I'd say a fair amount of attitude change was required to establish these rates. If there had been a wind, I feel that the entire system would have been considerably more difficult to control from the pilot's point of view. Ability to remain within ground-track limits was very good in the no-wind condition. Control feel, forces, deflections, and trim were good with the previous note that attitude changes were fairly large considering the no-wind condition.

Response to control inputs was fairly sensitive, and ability to hold heading was good. Turns-over-a-spot and ability to remain over a spot were very good since there was no wind. Attitude control was easily accomplished although to make small corrections, a fair amount of attitude change was required to translate.

Ability to initiate turns and stabilize and hold preselected turns was very good. Ability to stop on preselected headings also was very good. Ninety-degree crosswind turns - time was very nominal. No undershoot or overshoot tendencies.

Ability to establish heading and position over a spot was good. Control activity was minimal and control power was good. Precision hover was easy to establish and maintain although it did take pilot attention to monitor the aircraft attitude. The vehicle seemed to be on top of a ball with the tendency to fall off in a given direction, and it required considerable pilot attention to maintain a good hover. Once established, very minimal stick activity was required. It was excellent for vertical landing in a no-wind condition.

Quick stops were performed adequately fast. Excessive attitude changes were not required. Ability to hold heading and altitude was good. Control motions were not excessive.

Overall Evaluation

Objectionable feature - it was somewhat sensitive in response. I couldn't look away too long or I would initiate some movement in a given direction, although it was easy to catch and it took only a small correction to return the aircraft to where I wanted it.

Favorable feature - it looked a lot better because of the no-wind condition. I think that in a wind condition the pilot would have had a considerably different opinion of the aircraft. The workload would have gone up considerably. Special piloting techniques - none required.

CASE 343 (RERUN)

$X_u = Y_v = -0.20$ $\lambda = 0.3$

$M_u g = -L_v g = 0.33$ $\omega_n = 1.82$

$M_q = L_p = -0.30$ $\zeta = 0.06$

$M_\theta = L_\phi = -3.30$ No wind or gusts

PILOT D PR = A4-1/2 $M_\delta = 0.746$ $L_\delta = 1.062$

This particular configuration was stable, but was lightly damped in dynamic response in pitch and roll.

In the air-taxi-around-the-square, initiating motion was no particular problem in either direction. It required quite a bit of bank to be held going sideways. I was able to hold a rate of movement fairly well in both directions. Stops on the corners worked out pretty well. Attitude changes weren't excessive. Stayed within the ground-track limits. Control deflections were quite small. Response may have been just a little sluggish. Sensitivity seemed okay.

Turns-over-the-spot worked out real well. Gross attitude changes were controlled, where required. Turn rates and so forth were satisfactory. In the crosswind turns, the vehicle didn't seem to be able to gather much speed. Going into the wind, there was a slight undershoot tendency. Control activity didn't seem too great.

Precision hovers worked out real well. I was able to trim it and let it stand there hands off. Probably would have been okay for a vertical landing. Response in the system was such that it would take quite a bit of activity close to the ground. Quick stops worked out okay; no excessive attitude changes. Secondary dynamics didn't affect the evaluation.

Overall Evaluation

Objectionable feature was the lack of damping in pitch and roll. Frequency was such that it wasn't too difficult to compensate for it. Favorable features - it was stable and easy to fly the mission.

PILOT F PR = A4 $M_\delta = 0.757$ $L_\delta = 0.736$

This particular control system was characterized by random movement about a trim position. It was sort of like rolling around on the top of a ball throughout the entire flight. After a while it didn't cause too much of a pilot workload. I got used to the fact that this little bit of movement wasn't going to make much difference in my ability to control the aircraft or even cause the aircraft to move out of a reasonably stable hover. So once I got used to that particular characteristic, it was less undesirable than the initial impression.

CASE 343 (RERUN) (Continued)

The performance of the aircraft was a little limited. For a given attitude, I would like to have seen higher rates of speed across the ground. This was a no-wind evaluation and, with no wind, it was not real easy nor real comfortable to get a reasonable rate of movement across the ground for quick-stop maneuvers. If one were to project this into a wind situation, I'm sure that the system would be much less adequate than it was with no wind.

Control sensitivity was just slightly medium high in order to give a quickness of response to control inputs, and adequate control power without becoming a little bit jerky and oversensitive to control inputs. In the air-taxi-around-the-square, the ability to initiate motion at a reasonable rate was compromised by having to go to a very steep attitude for a slow rate; and the rate of movement across the ground was a little less than one would like to see for a given attitude change.

Ability to stabilize and hold preselected rates of movement was pretty good once I got used to this random movement about a trim position. It was not bad at all once I got used to the peculiarity of this system. Ability to stop precisely and come to a hover at the corners was quite good, primarily because I was not able to generate too fast of a rate across the ground; and I was able to modulate my control inputs and make a very precise stop at the corner.

Excessive attitude changes, if I had wanted a faster rate, might have been required but I was content to take a more moderate attitude change and accept the slower rate that resulted. Once I got used to the control system, the ability to remain within the ground-track limits was very good. Control feel was good, forces were not excessive, and deflections were not objectionable. Trimmability was only fair because of the random movement around trim. I wasn't holding any forces; however, the aircraft was demonstrating instabilities about that point.

Sensitivity to control inputs was also to this particular pilot's liking. Ability to hold heading was good. In the turns-over-the-spot, the ability to remain over the spot was very good. The small random movements about the trim position did not affect position. Therefore, I would have to say I was still in a precision hover even though there was some random movement of the aircraft about that position. Attitude control was easily maintained as long as I ignored this little rolling-about-on-top-of-the-ball situation.

Ability to initiate turn rate, stabilize and hold preselected turn rates, and stop on preselected headings, was excellent. In the turns into the wind, the time to accomplish the maneuver bordered on the high side because of the inability to get brisk rates of movement across the ground. There was a tendency on my part to undershoot the desired spot perhaps because of the no-wind conditions. The aircraft stopped a lot quicker than I thought it would when I approached the spot. It didn't coast up to it with a reasonable inertia characteristic like one often sees.

Ability to establish heading and position over the spot was good, again considering that one ignored the random movement. Control activity was not excessive. Control power seemed adequate. To establish and maintain a precision hover was good, again considering the random movements which didn't affect the position over the ground. It was very adequate for vertical landings, and control activity was nominal. I could stop as quickly as I wanted from whatever rate of movement was generated;

CASE 343 (RERUN) (Continued)

however, I would like to have seen a little brisker movement across the ground in order to initiate a quick stop.

Excessive attitude changes were not required. Ability to hold heading and altitude was good. It was compromised in terms of the altitude trying to generate a faster movement; therefore, the larger attitude changes introduced somewhat of an altitude control problem. I wouldn't consider it serious, however. No excessive control motions were required. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

The objectionable feature was the constant rolling around the trim position. While it did not result in aircraft movement across the ground, it was bothersome at first. Of course, after a period of time, the pilot adapted to it and was able to get used to it and acclimatized to it. The performance of the aircraft to control inputs and a given attitude change, resulted in very low rates of movement across the ground. It was marginally adequate for the no-wind dynamic maneuvers such as quick stops and moving across the square, so one would certainly like to see more vehicle response to attitude changes.

The favorable feature was the reaction of the aircraft to control inputs. The attitude changed at controllable rates and was much to the pilot's liking. I felt that I could control the attitude quite precisely. It was a very smooth control system after I learned to ignore the rolling around the trim point. No special piloting techniques were required.

CASE 344

$X_u = Y_v = -0.20$ $\lambda = 1.0$

$M_u g = -L_v g = 0.33$ $\omega_n = 0.76$

$M_q = L_p = -1.80$ $\zeta = 0.67$

$M_\theta = L_\phi = -1.21$ No wind or gusts

<u>PILOT D</u>   PR = A4 $M_\delta = 0.925$ $L_\delta = 1.017$

This particular vehicle was easy to fly during the mission. There was a slight oscillatory tendency in roll.

On the air-taxi-around-the-square - no problems here. Easy to initiate motion. No problem on holding the motion or the speed desired forward, sideways or backward. Stops at the corners were very easy. Pitch attitude changes and roll changes were not excessive. Ground track was easy to maintain. Control feel - on this particular one the sensitivity was turned up to get the response desired. It felt a little bit jerky right around the neutral point in both pitch and roll. More so in pitch.

Response to control inputs was satisfactory. Turns-over-the-spot - no problems here. Stayed over the spot. Crosswind turns - made them all in minimal time with no overshoot or undershoot tendency. Coming to a precision hover - real easy to maintain precision. Vehicle didn't seem real stable; however, it was real easy to fly and it would have been okay for a vertical landing. Quick stops - no problem. Attitude changes were not excessive. No problem with control motions. Satisfactory. Secondary dynamics did not affect the evaluation.

<u>Overall Evaluation</u>

Objectionable features were the kind of jerky movement in pitch and roll. Favorable features - fairly pleasant machine to fly and it was easy to complete the assigned mission.

<u>PILOT E</u>   PR = A2-1/2 $M_\delta = 0.609$ $L_\delta = 0.643$

This configuration was very nice to fly with only one drawback. The attitude changes to generate velocities seemed to be a little large to me. I noticed there was no wind, but I seemed to be getting a bobble in pitch throughout when maintaining a steady hover position. I finally concluded that I was putting little inputs in on the stick. After I finished evaluating, I tried it reducing the sensitivity slightly and it took away that problem. I was getting a little bobble in pitch and it was due to the very small inputs that I was inadvertently putting in on the stick.

CASE 344 (Continued)

Control sensitivity in pitch was likely a little high. Air-taxi-around-the-square - the ability to initiate motion was a little bit sluggish. The attitude required was too much. Had no problem stabilizing at a given rate. Could easily stop and hover precisely at the corners. Attitude changes tended to be a little large. Ability to remain on the ground-track limits - I think I could do it with no problems just about as well as I wanted to. Control feel, forces, etc. - no problems.

Response to control inputs seemed adequate in pitch and roll. Turning-over-the-spot was very nice. Crosswind turns - the attitudes required to initiate and stop the motion were a little larger than I liked. Precision hover was no problem with attitude or rates. Position control could be very precise. It was certainly adequate for landing and control activity was normal.

Quick stops - stopping was no problem. Excessive attitude changes were required to initiate the motion. Heading, altitude - no problem. Secondary dynamics - okay.

Overall Evaluation

The only objectionable feature that I could find was that the attitudes required to generate the velocity desired were larger than optimum. Favorable features - no effects of any external disturbances. Felt very solid. No special piloting techniques were required.

PILOT F PR = A3 $M_{\delta} = 0.569$ $L_{\delta} = 0.582$

This control system was evaluated under a no-wind condition. Generally, it was not too bad and it was responsive to the pilot's desires; however, it required fairly large attitude changes to initiate or stop movement rate. In a hover, I had to devote a fair amount of attention in monitoring precise attitude and making small corrections with the control stick in order to maintain the desired attitude. It had the tendency that one was on top of a ball, always just about ready to fall off in one direction or the other, requiring small corrections to maintain a desired position. I believe that a moderate wind condition would be sufficient to substantially degrade this control system.

Control sensitivities were selected at average rates to give a moderately fast reacting aircraft, yet not too sensitive to small control stick inputs. In the air-taxi-around-the-square, the ability to initiate motion was quite good. Again considering the no-wind condition, a slightly larger attitude change was required than one might normally expect. Ability to stabilize and hold preselected rates of movement was good. Ability to stop precisely and hover at the corners also was very good.

Attitude changes - considering the overall situation - no wind and so forth - weren't really excessive. They were greater than one would normally expect under the conditions. Ability to remain within ground-track limits was very good. Control feel was good, forces were adequate, deflections were normal, and trimmability was good. There was that feeling around trim of looseness in the control system, looseness in response, and random response of the aircraft to what the pilot really desired. Response to control inputs was predictable, and sensitivities were moderate in all axes.

Ability to hold heading was very good. Turns-over-a-spot and ability to remain over a spot were excellent, and certainly enhanced by the no-wind conditions. Attitude control, again due to the no-wind condition, was no problem.

Ability to initiate turn rates was good, and one could stabilize and hold preselected turn rates at the pilot's discretion. Ability to stop on preselected headings also was very good. In the 90-degree turns into the wind, time to accomplish the maneuvers was normal. There were no overshoot or undershoot tendencies. Ability to establish a position over a desired spot was good. Control activity was minimal and control power was adequate.

It was basically easy to establish and maintain hover, considering that it did require a fair amount of pilot attention to all attitude changes and fairly frequent but small stick inputs to maintain the desired hover. It was very adequate for vertical landings. Control activity was fairly high in frequency, but relatively low in amplitude. Relative control activity for precision hover was pretty good.

Quick stops were accomplished as quickly as I desired. Attitude changes were not excessive, but again they were quite large considering the no-wind conditions. To attain a fairly fast rate did require quite a large attitude change throughout all of these maneuvers. The rates and attitudes were predictable, so the pilot had confidence in his ability to control rate and attitude. Control motions were not excessive in the quick-stop maneuvers. Secondary dynamics did not seem to enter into this.

Overall Evaluation

The objectionable feature of this system was the apparent looseness of the control system about trim and while attempting to maintain a precision hover, which resulted in slight random attitude changes requiring frequent pilot inputs to the stick. Favorable features - it was a responsive control system, it reacted to the pilot's inputs in a predictable manner, and the maneuvers were executed quite precisely. No special piloting techniques were required.

CASE 345

$X_u = Y_v$	$= -0.20$	λ	$= 1.0$
$M_u g = -L_v g$	$= 0.33$	ω_n	$= 3.00$
$M_q = L_p$	$= -0.80$	ζ	$= 0$
$M_\theta - L_\phi$	$= -0.21$	No wind or gusts	

PILOT D PR = A4 $M_\delta = 0.649$ $L_\delta = 0.741$

This particular configuration had medium damping both in roll and pitch. It didn't seem too stable in either axis.

Air-taxi-around-the-square - forward motion was fairly easy to initiate. There was an oscillation in pitch when trying to maintain the desired motion, and also a slight roll oscillation. Rate of movement required minor adjustments of pitch to maintain preselected rate.

There was no difficulty in coming to a hover at the corners. Attitude changes were not excessive during any of the maneuvers. Ground track was fairly easy to maintain. Control feel and forces - no comment. Deflections - very small control inputs were required. Response to control inputs was satisfactory in all axes. Turns-over-the-spot - no problem remaining over the spot.

Attitude control was satisfactory. Again, there was a slight tendency to over-control or cause a slight lateral roll oscillation; not so much in pitch (slight tendency there). There was no difficulty initiating the turn rate desired or in stopping on the preselected heading. Crosswind turns - time to accomplish maneuver was satisfactory. No overshoot or undershoot tendencies.

In establishing precision hover, there was a little too much stick activity required in the hover. It didn't cause any difficulty but was slightly annoying. It would have been adequate for a vertical landing. Control activity was moderate but it was easy enough to fly.

Quick stops - no problems here. Stops forward - slight attitude change was required. Going sideways in both directions - no difficulty there. Control motions were very small. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - it would be desirable to have a little more stability, in both roll and pitch, and a little higher damping in both roll and pitch. Favorable features - nothing really outstanding. It was fairly easy to fly. No comments on piloting techniques.

CASE 345 (Continued)

PILOT E PR = A3 M_δ = 0.486 L_δ = 0.433

This configuration was quite reasonable to fly. The only complaints were in pitch; no real complaints in roll. No comments on the sensitivity. The air-taxi maneuver - the motion could be initiated satisfactorily in both directions. Stabilized rate of movement could be obtained and it was relatively easy to stop. It could be hovered precisely.

Attitude changes in pitch tended to be large, and there was a general feeling that I had to concentrate just a bit to make sure it did not get away. The pitch attitudes required were not really excessive, but there was a little lack of confidence that I was in complete control. I could fly the ground track with no problems.

Response to control inputs was fine in roll. In pitch, there was a feeling that the rate was coming on a little too fast. An extra bit of concentration had to be applied but the response was good enough that one could control it completely. Turning-over-a-spot was no problem.

There did not seem to be any effects of winds, mainly because I do not think there were any winds. Ninety-degree crosswind turns - lots of rudder required. Control activity tended to be in pulses in pitch. Precision hover - no problems.

Quick stops - could be stopped as quickly as I wanted to stop it. Attitude changes were moderate in pitch. Same comments as before about the rate of change of attitude. Control motions in pitch tended to be in short bursts.

Overall Evaluation

Objectionable features - I have already mentioned them. Favorable features - the roll was good. Control response in general was crisp, so that the machine could be flown quite accurately. A little more attention had to be given to the pitch.

PILOT F PR = A3 M_δ = 0.719 L_δ = 0.763

This was a no-wind evaluation and the control system was characterized as quite pleasant. It was quite good in most respects but slightly sluggish in response, considering the no-wind condition. It took a little while for the aircraft to attain an attitude and then to initiate the motion. Attitudes were slightly exaggerated in order to attain reasonable rates of movement across the ground.

Control sensitivity was just slightly higher than normal in order to make the aircraft respond a little faster to control inputs and yet not too high that it was oversensitive to small inputs. On the air-taxi maneuver, the ability to initiate motion was a little bit slow, but if one wasn't too impatient he could initiate the rate he had in mind. It did take a fair amount of attitude change in order to initiate the motion.

I could stabilize and hold preselected rates of movement quite well although it did take a little longer than desired to attain them. Ability to stop precisely and come to a

hover at the corners was good as long as I led the stopping point, because of the time between control inputs and change in aircraft rate of movement across the ground. Attitude changes were not excessive; however, they were larger than I would normally expect in order to achieve the rates across the ground.

Ability to remain within the ground-track limits was good. Control feel was good. Forces, deflection, and trim were all normal. Response to control inputs was a little bit slow and sluggish. Sensitivities were all right and ability to hold heading was good. In the turns-over-the-spot, the ability to remain over the spot was quite good due to the no-wind conditions. Attitude control in pitch and roll was not much of a problem. It was easy to maintain level attitude throughout the turn. Ability to initiate turn rates and hold a predetermined rate was good. I could stop on preselected headings very easily.

Time to accomplish turns into the wind was normal; actually there were some overshoot or undershoot tendencies because I had been used to anticipating wind effects. I wouldn't say the overshoot or undershoot tendencies were due to the control system, but merely pilot habit pattern. Ability to establish heading and position over the spot was good. Control activity was minimal and control power seemed adequate.

Ability to establish and maintain a hover was easier than normal, due to the no-wind conditions. Very good for vertical landing. Control activity was minimal for a precision hover maneuver. Quick stops could be accomplished reasonably fast and excessive attitude changes were not required. I felt that the aircraft stopped sooner than anticipated on one quick-stop maneuver, much as if there was wind. However, there wasn't any wind, so that was a sort of peculiar maneuver in this particular situation. I don't know what to blame that on.

Ability to hold a heading and altitude in the quick-stop maneuver was normal, and control motions were normal. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features were the slight sluggishness in response to control inputs, and the rather large attitude changes required to initiate movement over the ground. Favorable features - it was maneuverable and fairly predictable. No special piloting techniques were required.

CASE 346

$X_u = Y_v = -0.050$ $\qquad M_\delta = L_\delta = 0.300$

$M_u g = -L_v g = 0.330$ $\qquad \lambda = 0.087$

$M_q = L_p = -4.289$ $\qquad \omega_n = 3.038$

$M_\theta = L_\phi = -9.389$ $\qquad \zeta = 0.700$

PILOT D PR = A6

This particular configuration was very stable. However, it was extremely lacking in control response; also, the stick movements required were excessive, and several times during the flight there was not sufficient available control.

Air-taxi-around-the-square - on forward motion, as long as everything was trimmed out smooth, it was easy to maintain the movement. Once it was disturbed, because of the slow response of the vehicle, it was hard to restabilize. This was true going sideways also. Coming to a stop in hover at the corners - here again, it was difficult to do anything precisely because of the slow response. Attitude changes were not excessive.

Staying within the ground track was difficult because of the slow response. Control feel, forces and deflections were excessive, sometimes reaching the limits. Forces were high requiring trimming. Response was too slow, way too slow. Sensitivity was too low.

Turns-over-the-spot - because of the slow response it was a little difficult to stay in a precise position. Turn rate - no comment. Crosswind turns - time was okay and there was a slight tendency to overshoot because of the slow response. In a precision hover - once the attitude position was established and the vehicle trimmed, it was entirely satisfactory. Because of the extremely slow response, it would be doubtful for a vertical landing.

Quick stops - no particular problem in stopping forward. Translating forward required full forward stick to get any speed up at all. Sideways going with the wind, coming to a stop - full right stick input was required to stop and then it did overshoot. Going into the wind - no particular problem to translate sideways into the wind. Required full right wing down. Control motions were excessive. Secondary dynamics had no effect on the evaluation.

Overall Evaluation

Objectionable features - the extremely slow response of the vehicle, excessive stick movements to command an attitude, plus lack of necessary control power. Reached the limits of the control stick in several cases. Favorable features - very stable.

CASE 346 (Continued)

PILOT E PR = U7

This one was unacceptable. There was a lack of control power in pitch and, to a slightly lesser extent, in roll.

Air-taxi-around-the-square - could initiate motion all right, taking it slow and easy. Kind of a lazy configuration. Could do the square all right. The attitude changes, provided one could anticipate well in advance where he wanted to stop, were normal.

Large control deflections were required to generate the attitudes, and large forces had to be held. I did not like that. Response to controls - they were the same in pitch and roll and would have been quite adequate with more control power.

Turning-over-the-spot - no problem. Ninety-degree crosswind turns - took a long time to accomplish the maneuver. It could be done, though. Control activity - slow, very large. Control inputs - large forces. Precision hover - no noticeable effects of external disturbances. Could be landed. Control activity - I have already mentioned that.

Quick stops really derated it most severely, particularly in pitch. To move with less than optimum velocity I was on the forward stop most of the time, and one does not like to be flying with the stick on the stops. In relation to the speed that one could attain, it could be stopped all right. A good deal of anticipation was required since large control inputs were required to change the attitude. No comments on secondary dynamics.

Overall Evaluation

Objectionable features - low control power in pitch and, to a lesser extent, in roll severely derated the configuration. Favorable features - both in pitch and roll, the response characteristics were quite nice.

PILOT F PR = A3

This control system was a big airplane control system characterized by a very smooth but somewhat sluggish control response and high force gradients on the stick. It gave the overall impression of a large aircraft. However, it was very capable of being precisely controlled, although it was not very quick in its response.

Control sensitivity was fixed. Air-taxi-around-the-square and ability to initiate motion, stabilize at preselected rates, and maintain track on the square pattern were excellent. It was somewhat sensitive to wind but this was not annoying and easily compensated for. Control force and control feel, as I stated previously, were those of a heavy aircraft with heavy force gradients. Moderate deflections were required of the stick in order to accomplish the maneuvers desired.

Response to control inputs was slow. Ability to hold heading was excellent. Turns-over-a-spot - ability to remain over the spot was above average as long as one compensated for the wind. The aircraft felt very stable and it was very easy to hold over the spot when I corrected for the wind. Attitude control was moderate.

Pitch and roll changes needed to hold the spot were a little less than moderate. Ability to initiate turns was very good. Ability to stabilize and hold preselected rates of turn and stop on preselected headings was very good. Ninety-degree turns into the wind - because of the big airplane feel and the low response of the aircraft to control inputs, the time to execute the maneuver was higher than normal but not seriously degrading. There were very few overshoot or undershoot tendencies.

Ability to establish a heading and position over the spot was very good. Control power might be considered low, but not control activity. Precision hover was excellent for attaining and maintaining a very precise hover, both in attitude and angular rates. Turns in a hover, as stated previously, were somewhat affected by the wind, but not more than normal. It was excellent for vertical landing. There was very little control activity during hover and the vertical landing maneuver.

Quick stops could not be performed as quickly as most pilots would like due to the sluggish response to control. Excessive attitude changes were not required; however, I ran out of forward stick in attempting to accelerate the aircraft at a level altitude during the quick stop into the wind. I was limited in attaining a faster rate by the control stick stop thus degrading the quick-stop maneuver.

Ability to hold heading and altitude was very good. Quite large control stick movements were required in order to counteract attitudes or attain attitudes that were wanted. The movements were large; however, they were not frequent and they were easily controlled at the pilot's desire. Secondary dynamics did not enter into this.

Overall Evaluation

Objectionable feature was the sluggishness of the response of the aircraft. Favorable feature was the very smooth, very precise control system. No special piloting techniques were required other than to compensate for the low control power and low response time to attitude changes or to control inputs. I had to lead just a little bit more than normal to make the aircraft react as I desired.

CASE 347

X_u	$= Y_v$	$= -0.05$	M_δ	$= L_\delta =$	0.450
$M_u g$	$= -L_v g$	$= 0.33$	λ	$=$	0.087
M_q	$= L_p$	$= -4.289$	ω_n	$=$	3.038
M_θ	$= L_\phi$	$= -9.389$	ζ	$=$	0.700

PILOT D PR = A5

This particular configuration was very stable, very slow in response, and heavily damped. Air-taxi-around-the-square - easy to initiate motion and stabilize on the preselected rate of movement in both directions - forward and sideways. There was a lot of stick travel required. No particular problem in stopping at the corners.

Excessive attitude changes on coming to the stops - it did take a little forethought because of the slow response of the vehicle. Attitude changes weren't excessive. Stayed within the ground track fairly well. Control feel - because of the large deflections required, the forces seemed high when trying for varying attitudes unless they were trimmed out. Response was okay. Sensitivity also was low.

Turns-over-the-spot - stayed within the spot fairly well. Attitude control - control movements again were excessive here. No problem on initiating the turn rate or holding the preselected turn rate coming to a stop. Crosswind turns - first one overshot; again attributed to the slow response of the vehicle. Precision hovers after coming to a stop were no problem. It was very stable and could be trimmed and flown "hands off." The vertical landing was doubtful here because of the slow response of the vehicle.

Quick stops - forward, no problem coming to a stop. Sideways with the wind, I ran out of lateral control. I had the stick in the full-right position coming to a stop. Control motions here were excessive. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - response was too slow. Travel of the stick was excessive. Favorable features - very stable. Special piloting techniques - had to preplan or lead any control or vehicle response. Had to lead it by a certain amount.

PILOT E PR = A6

It was not very pleasant to fly simply because of the lack of control power. The control sensitivities - I wish I'd had the opportunity to set them.

The air-taxi-around-the-square - the attitudes required to initiate motions put me very nearly at the stops. The rate of movement that I could get was not quite what

I'd like to have had. Tended to not be able to stop as quickly as I wanted in coming to a hover at the corners. The control throws that I had to use were really excessive. As a result, the forces were somewhat objectionable.

Nothing happened very fast, so I could remain within the ground-track limits with some effort. Response to control inputs seemed to be adequate except that the control power was much less than desirable. Turning-over-the-spot was a little bit of a problem in terms of the attitude changes required as I turned around. And the control throws to control the attitude were too much.

The 90-degree crosswind turns were somewhat difficult to accomplish because of the control throws required to generate the attitudes; so I couldn't establish a position very precisely, not immediately anyway. Precision hover - I've already commented on that.

Quick stops was perhaps the item that derated it most. I could not generate the velocity that was desirable. As a matter of fact, I was right on the stops on the longitudinal quick stop. The control throws to stop the machine, even at a moderate velocity, were excessive, with the result that I tended to overshoot the spot. The same thing happened laterally. I did hit the stops on the stick and I didn't like that. Secondary dynamics - no problems.

Overall Evaluation

Objectionable features - a lack of control power requiring excessive control throws to the point that in normal maneuvers I hit the stops several times.

PILOT F PR = A1

This was an extremely smooth, easy, and pleasant control system to fly, with the exception that it gave the pilot the opinion that the vehicle was not very maneuverable but very precisely controlled. As long as one was willing to take a less responsive vehicle in terms of quickness, this control system enabled one to do almost anything with the aircraft in terms of precision hovering and maneuvering but with a lesser speed.

Control sensitivity was fixed for the test. In the air-taxi-around-the-square, motion was easy to initiate as long as I didn't want to be quick about initiating a motion. As long as I was content to be a little bit grandmotherly with the type of maneuvers that I was going to execute, the ability to initiate motion, to stabilize rates and headings, and to stop precisely with this particular system, was outstanding.

The control forces, feel, and deflections gave the impression of a somewhat bigger type of machine rather than a small maneuverable aircraft. Ability to hold heading was excellent in this particular system. Turns-over-a-spot - as long as a person could anticipate the wind effects correctly, turning-over-a-spot was a "piece of cake."

It was extremely easy to maintain rates and relative position except for the wind effects, which a person could easily learn to overcome. Ability to stop on a preselected

heading was excellent. Ninety-degree crosswind turns - it was a little difficult to initiate a crisp rate of movement across the ground, again due to the sort of large aircraft feel of the control system and lack of maneuverability found in some machines. However, I could control the attitude of the aircraft and make the aircraft decelerate and turn into the wind and stop on the spot desired with a very minimum of pilot effort. Gusts and winds seemed to have much less effect on this control system.

The only possible concern would be the fact that the maneuverability was more restricted with this particular control system. Precision hover and the ability to establish and maintain a precise control were excellent. It was excellent for vertical landings. Control activity was very minimal. Quick stops - again lack of maneuverability made the quick stop a slow maneuver but it was certainly a precise one.

In order to gain a little maneuverability, altitude control suffered somewhat in the test task when trying to bring in a little extra power to get a little more airspeed. However, even putting in large control displacements did not create any attitude control problems in the aircraft.

The ability to hold a precise heading and altitude was good. On the downwind quick stop, however, I overshot quite badly by not anticipating soon enough when to put in opposite aileron in order to give the aircraft enough time to decelerate and stop on the desired spot. However, a little experience in this particular control system would enable this maneuver to be accomplished quite precisely. Directional and height dynamics did not affect any of the maneuvers.

Overall Evaluation

The most objectionable feature was the apparent lack of maneuverability of the vehicle. This did not detract from the ability to accomplish the given test tasks; however, they could not be accomplished with quite the crispness perhaps some people would like. I did not find this particularly objectionable. I was content to accomplish some of these maneuvers in a slower manner.

The favorable features - it was a very smooth control system, enabling precise attitude position changes to be accomplished. No special piloting techniques were required other than perhaps a little bit of anticipation to compensate for the lack of specific maneuverability that the system demonstrated.

CASE 347 (RERUN)

$$X_u = Y_v = -0.05 \qquad M_\delta = L_\delta = 0.450$$

$$M_u g = -L_v g = 0.33 \qquad \lambda = 0.087$$

$$M_q = L_p = -4.289 \qquad \omega_n = 3,038$$

$$M_\theta = L_\phi = -9.389 \qquad \zeta = 0.700$$

PILOT F PR = A3

This was a very, very stable control system, and also quite a sluggish control system, characterized by very good trimmability and high stability. I just sat up there, trimmed it up hands-off and the thing would just stay there. It did not seem to be affected too much by winds other than fairly large displacements of the stick to compensate for relative wind effects. The stick deflections were quite large although the aircraft response to control inputs was predictable, and certainly controllable. Overall it gave a feeling of a big airplane. It was a sluggish but predictable response. Control sensitivity was fixed.

In the air-taxi-around-the-square, the ability to initiate motion in each direction, while sluggish, was predictable, and one could initiate a motion pretty much at the pilot's discretion. It wasn't a snappy response to control inputs but it was very predictable. As long as one wasn't wanting a very fast response he could easily stabilize and hold preselected rates of movement, although it took a little bit of time to alter them. But it was very predictable.

Stopping precisely and coming to a hover at the corners initially showed a tendency to overshoot, because of the sluggishness of the response of the vehicle. However, I soon learned to put in larger stick deflections and then I could make the aircraft react a little faster and at the pilot's discretion. Excessive attitude changes were not required.

Ability to remain within ground-track limits I thought was very good. Control feel - it had the feel of a big airplane. I had much larger stick deflections than with a lot of aircraft; however, it did not lead to overcontrolling tendencies. Trimmability was excellent. Forces were not excessive. I could control the aircraft and wasn't afraid to put in large deflections to make the aircraft perform as well as I wanted. Yet, I could slow the aircraft down or stop it pretty much where I wanted to, once I got used to the complete characteristics of the system. There certainly was a very low sensitivity to inputs as far as aircraft response was concerned. Ability to hold heading was good.

In the turns-over-a-spot, the ability to remain over the spot was good. If one anticipated the wind, he might put a correction in a little too soon and overcompensate; but once he had the wind effect under control, the ability to remain over the spot was excellent. Attitude control in roll and pitch also was good. Ability to initiate turn rate and stabilize and turn on preselected turn rates with a stop on preselected headings was excellent.

CASE 347 (RERUN) (Continued)

In the 90-degree turns into the wind, I could accomplish the maneuver in normal time, once I got used to putting in larger stick deflections to make the vehicle respond at my discretion and at the rate desired. There was an overshoot tendency in turning into the wind because of the apparent inertia of the aircraft and the initial reluctance to use fairly large stick deflections to make the aircraft react as I wanted, but I think a pilot would be able to quite accurately predict his stopping point in this type of maneuver very quickly. Ability to establish heading and position over the spot was covered previously.

In terms of a little bit of pilot experience, I think one could do real well in establishing a hover. After turning into the wind, the control system was very good to accomplish a hover. I had large deflections with this control system, but it was not objectionable as far as this pilot was concerned, and control power was adequate considering that the whole system was quite sluggish in response. Now if increased control power would decrease the sluggish response of this vehicle, I might say the control power was not adequate. Ability to establish and maintain precision hover was excellent. It was excellent for vertical landing. Control activity, once trimmed up in a hover, was nil.

Quick stops - once again with large control deflections, I could accomplish the maneuver as quickly as desired. Excessive attitude changes were not required in order to accomplish reasonably fast quick stops. Ability to hold heading and altitude was good. Control motions, while large in deflections, were not erratic. Control of the aircraft I thought was quite predictable; therefore, I will not consider control motions excessive. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features would be the relatively sluggish response of the aircraft to control inputs, the real big airplane feeling, the associated tendencies to initially overshoot, and the large control deflections required to make the aircraft respond as the pilot required.

The desirable features - it was an extremely predictable control system, very stable, very docile so to speak, easily trimmed up; and once the pilot discovered that he could put in large control deflections and make the aircraft react a little quicker, he never had any problems of losing control or overcontrolling.

So, overall, I thought it was a very predictable control system and, as long as I didn't mind a real big airplane feel, it was quite favorable. Special piloting techniques were not required except that I didn't have to be afraid in this particular system to use larger than normal control deflections in order to make the aircraft perform a little bit more responsively, a little quicker. The time between initiating control action and the actual time that the vehicle would stop, was fairly long but would be adjusted to easily by the average pilot.

CASE 348

$X_u = Y_v$	$= -0.05$	$M_\delta = L_\delta$	$= 1.350$
$M_u g = -L_v g$	$= 0.33$	λ	$= 0.087$
$M_q = L_p$	$= -4.289$	ω_n	$= 3.038$
$M_\theta = L_\phi$	$= -9.389$	ζ	$= 0.700$

PILOT D   PR = A4

This particular configuration was stable in roll and pitch. Response was very good and it was fairly easy to fly. It was oversensitive in pitch, not so much in roll.

Air-taxi-around-the-square - it was easy to initiate the motion and maintain the preselected rate forward, sideways and backwards. Precise hovers at the corners worked out very well. Pitch and roll changes were not excessive, and it stayed fairly well within the ground-track limits. Control feel, forces, and deflections - feel was sensitive, especially in pitch. Forces and deflections were very small. Response was good. Sensitivities - oversensitive in pitch.

Turns-over-the-spot worked out well. Pitch and roll changes were satisfactory. Turn rates and so forth were satisfactory. Crosswind turns - time was not excessive. Didn't overshoot or undershoot. No problem coming to a stop. Hover was easy to establish. However, the quick response in pitch was annoying. Control activity was very small. The quick stops worked out very well again, going forward and sideways in either direction. Secondary dynamics didn't affect the evaluation.

Overall Evaluation

Objectionable features - the oversensitivity in pitch was annoying. The vehicle responded rather jerkily. Favorable features - very stable. Other than the oversensitivity in response in pitch, it was a very nice machine. The pitch sensitivity deficiency should be corrected.

PILOT E   PR = A2

I liked it - it was quite nice. I initially thought it was perhaps oversensitive but after flying the task I found it quite desirable.

Air-taxi-around-the-square - no real problems. I could hover quite precisely with no problems. With external disturbances, roll and pitch seemed very similar, but there was a tendency to get a little bump in pitch. It seemed to be a characteristic of the simulator. I've noticed it before anyway.

The roll and pitch seemed about of equal sensitivity and yet the small inputs in pitch produced a kind of bump in the simulator, but I ignored that. Feel, forces, deflections - no complaints really. There was a noticeable deflection required to

generate the proper attitude. It was not a major problem. Response to control inputs in both axes was excellent.

Turning-over-a-spot - no problems. 90-degree crosswind turns - nothing noticed. Precision hover - no external disturbances coming through. Certainly adequate to land. Control activity was reasonable.

Quick stops - reasonable attitude was required to initiate the motion but it could be stopped as quickly as desirable, and the attitude changes were moderate. No problem with heading or altitude. Control motions were normal.

PILOT F PR = A3

This control system was basically very well-behaved and predictable, and enabled the pilot to make the vehicle perform pretty much as desired. There was one detrimental aspect of the system: close to the stick center, there seemed to be spurious, infrequent, very small aircraft or cockpit responses to very small inputs into the control stick so that I was always balancing right up on top of a ball; I had to work a little bit to stay right on top. However, it did not prevent me from making the vehicle move and maneuver at my discretion. It was more of an annoyance than a detraction from the ability to make the aircraft perform.

There was fixed sensitivity, and in the air-taxi tracking maneuver, the ability to initiate motion was adequate in all directions. Ability to stabilize and hold preselected rates of movement also was very good. I could stop precisely and come to a hover at the corners. I overshot on the downwind leg, through lack of properly anticipating wind effects. Excessive attitude changes were not required. Ability to stay within ground-track limits was above average.

Control feel was good except for the comment that I made initially in terms of the annoyance of the very small movements of the aircraft to inadvertent minor inputs to the stick. Control forces and deflections were adequate as was trimmability. Response to control inputs was to this pilot's liking in all axes. The stick was over-sensitive about the neutral point, but regarding vehicle response to control inputs, it was very good. Ability to hold heading also was good.

Turns-over-a-spot and ability to remain over a spot were very good. Attitude control in the pitch and roll axes was excellent. Ability to initiate turn rates was good. Ability to stabilize and hold preselected turn rates and stop on a heading also was good. Ninety-degree crosswind turns were accomplished in a normal manner, with no over-shoot or undershoot tendencies. Ability to establish headings and positions over the spot was above average.

Control activity was minimal and control power seemed adequate. Precision hover was easily established and maintained with the exception of the small annoying movements about the hover trim point, but it did not require any great amount of pilot attention to remain in a precise hover over a predetermined spot; however, there were those annoying movements that I mentioned previously. It was very adequate for a vertical landing, and control activity for basic maneuvering and staying in a hover was good except for that aforementioned annoyance.

CASE 348 (Continued)

Quick stops were accomplished as quickly as I liked, without excessive attitude changes; ability to hold heading and altitude was very good. Control motions were not excessive. Secondary dynamics did not seem to enter into this.

Overall Evaluation

The objectionable feature was the spurious, minor, but very quick vehicle responses around the trim point in a hover and during the other maneuvers. It did not affect the ability to maintain positions or to attain or maintain rates of movement, but it was basically an annoyance factor in flying the vehicle.

Favorable features - it was a smooth and predictable control system, the aircraft was able to be maneuvered at the pilot's discretion, and basically it was a good system. No special piloting techniques were required.

<u>CASE 349</u>

$X_u = Y_v$	$= -0.05$	$M_\delta = L_\delta$	$= 4.050$
$M_u g = -L_v g$	$= 0.33$	λ	$= 0.087$
$M_q = L_p$	$= -4.289$	ω_n	$= 3.038$
$M_\theta = L_\phi$	$= -9.389$	ζ	$= 0.700$

<u>PILOT D</u> PR = U7

This particular configuration was oversensitive in roll and pitch. Response was extremely fast. There were PIO tendencies both in roll and pitch.

Air-taxi-around-the-square - initiating motion caused a lot of oscillations in roll and pitch, forward, sideways, and going backwards. It was difficult to hold and stabilize on a particular rate of movement. Hovers on the corners weren't very precise because of the continuous oscillations in pitch and roll. It seemed as if the roll oscillation was more noticeable than the pitch.

Attitude changes weren't excessive. It stayed fairly well within the ground track. Control deflections were very small. Response was extremely rapid in roll and pitch. Sensitivity was much too high. Turns-over-the-spot remained fairly well over the spot.

Attitude control in pitch and roll was satisfactory; however, again, there was continuous oscillation. No comment on turn rates - they were satisfactory. Crosswind turns - time was not excessive. When a quick pitch correction was required, there was a tendency to get into a mild PIO. Control activity - very small stick movements. Precision hover - the oscillations would stop hands-off, but stability, or lack of stability, was such that the pilot could only take his hand off briefly.

Quick stops worked out fairly well. The forward quick stop resulted in a slight PIO in pitch, and the lateral quick stop resulted in a slight PIO in roll. Control motions, again, were very small. Secondary dynamics did not affect the evaluation.

<u>Overall Evaluation</u>

Objectionable features were the overly sensitive control reactions. Response was extremely fast, making it difficult to fly. Oscillations of the vehicle were such that it was impossible to hold the control stick in the neutral position. The vehicle passed its oscillation to the pilot and in turn to the control stick.

CASE 349 (Continued)

PILOT E PR = U7

The vehicle was oversensitive. Response characteristics were excellent, but the control sensitivities were much too high both in pitch and roll.

The air-taxi-around-the-square - I could do the job, but I was concentrating so hard on not overcontrolling that I couldn't do it as desired. With the level of concentration required, I could remain within the ground-track limits. The control deflections were very small. Response to control inputs, as I said, was excellent. Sensitivities were much too high. I had a little trouble with heading control in the lateral translation.

Turn-over-the-spot - some problem with trim and attitude control, but not a great problem. Ninety-degree crosswind turns - same comment as before, just oversensitive. All the concentration went into not overcontrolling. I was not able to do the task the way I'd have liked. Precision hover - with high concentration, I could maintain position adequately. Turbulences were coming through in pitch attitude and roll attitude. I think one could land it.

Quick stops - I could stop it in spite of the sensitivity because of the good response characteristics. I didn't hesitate too much to use the required attitude, but any very abrupt input led to a very fast oscillation before getting it under control. The good response characteristics almost made up for the other deficiencies.

Overall Evaluation

The major deficiencies were the sensitivity and the turbulence response. The performance was adequate, but the compensation and concentration were too high to perform the mission.

PILOT F PR = U7

This control system was characterized by extremely fast attitude reaction to control inputs, but by extremely slow and sometimes inadequate performance of the aircraft in reacting to the attitude changes. Also, there were much more difficult problems of height control, depending upon what I was doing with the control stick. In a hover and making turns, height control was not a problem, but as I changed the attitude to translate forward or to move forward or sideways there was much more difficulty in controlling the attitude and much more collective activity to compensate for attitude changes.

The control sensitivity was fixed but extremely fast reacting. I felt more tendency towards PIO in the lateral axis than in the pitch axis. It was a very rough ride overall. It was impossible to put in small control attitude changes and have the aircraft react smoothly at the pilot's discretion. In the taxi-around-the-square, the ability to initiate motion in each direction was poor. I could change the attitude but then had to wait a little while for the rate of movement to pick up. This made it difficult to stabilize and hold preselected rates of movement and to stop precisely on the corners. I had a definite tendency to overshoot.

CASE 349 (Continued)

Excessive attitude changes might have been required to get increased aircraft performance. As long as I was content to accept slow rates, excessive attitude changes were not required. Ability to remain within ground-track limits was fair. Control feel - it was too quick a reacting control system. The forces were okay. Deflections did not seem very large and the aircraft could be trimmed up. But in response to control inputs, the aircraft changed attitude a little too fast and there was a discrepancy between attitude changes and performance of the aircraft in terms of rate of movement across the ground.

The aircraft attitude response was too sensitive to control inputs. Ability to hold heading was good in the tracking maneuver. In the turns-over-a-spot, the ability to remain over a spot was okay. Attitude control in pitch and roll did not seem to be as affected by wind as some other systems. Ability to initiate turns was okay. Ability to stabilize and hold preselected turn rates was average, and ability to stop on preselected headings was average. Ninety-degree crosswind turns had definite overshoot tendencies. There was difficulty in monitoring and maintaining altitude. I could not attain rates of movement which I desired and had difficulty, because of concentration with height control, in establishing heading in a position over the spot that I desired.

Control activity, especially collective, was excessive in the turning maneuvers. Adequacy of control power - the aircraft changed attitudes very fast but the attitude change did not seem to result in sufficient aircraft performance. Ability to establish and maintain a precision hover was, in terms of relative position in the air, not too bad. Once established, it was reasonably easy to maintain. However, it was not a smooth maneuver. Constant small attitude changes were occurring; however, translation over the ground was not taking place. It was adequate for vertical landing. Control activity was nominal for a precision hover maneuver.

In the quick stops, I could not accelerate over the ground at a reasonably comfortable rate. Attitude had to be maintained for an extremely long time to slow down the rates of movement across the ground, and the whole maneuver was much slower than I preferred. Altitude changes were occurring during this maneuver. Heading was not much of a problem, but altitude was. Control motion was not excessive in stick deflections, but probably there were more control inputs in this maneuver than normal.

Height dynamics did affect this evaluation; directional did not. In other words, the fact that with attitude changes I was having difficulty controlling the height, did feed back and make the attitude more difficult to control.

Overall Evaluation

Objectionable features - the rough ride, the lack of performance of the vehicle with given attitude changes, and too fast an attitude change to control input. Favorable features - don't know of any. Certainly the objectionable features overshadow any desirable features of this system.

Special piloting techniques - I had to be careful to keep from introducing a PIO, particularly in the lateral axis. Although this may have been a false impression, I got numerous frequent attitude changes. But it did not seem to affect the performance of the vehicle in terms of rates of movement across the ground.

CASE 350

$X_u = Y_v$	$= -0.05$	$M_\delta = L_\delta$	$= 6.075$
$M_u g = -L_v g$	$= 0.33$	λ	$= 0.087$
$M_q = L_p$	$= -4.289$	ω_n	$= 3.038$
$M_\theta = L_\phi$	$= -9.389$	ζ	$= 0.700$

PILOT D   PR = U8

This was an unstable, extremely-fast-responding, very-sensitive-flying vehicle.

Air-taxi-around-the-square - a lot of oscillations in pitch and roll. Occasionally there were PIO's in both pitch and roll, more so in pitch. It was difficult to stablilize and hold any rate of movement. Hovers at the corner were not precise at all because of the continuous and rapid oscillations. Pitch and roll attitude changes were not excessive. It stayed fairly well within the ground track. There were very small control deflections. It was difficult to trim, had extreme sensitivity on the stick, and had a lack of stability to reach a trim condition. Response was much too fast. Pitch and roll were extremely sensitive.

Turns-over-the-spot worked out fairly well. Pitch and roll attitude changes - here again, there were continuous oscillations and PIO's in pitch and roll, mostly in pitch. Turn rates - no comment. Crosswind turns - time was okay and the vehicle did not overshoot or undershoot. There was a tendency to go a little slower because of the difficulty in flying this vehicle. There was a lot of control activity, most of it coming from the inability to hold the control stick still. Vibrations of the vehicle were passed on to the control stick.

Precision hovers, again, weren't very precise, because of the continuous oscillations. Vertical landing probably would have been pretty scary. Quick stops worked out okay; again, with lateral or longitudinal PIO every now and then. Control motions again were real slow. Secondary dynamics did not affect the evaluation.

Overall Evaluation

The objectionable features were the lack of stability, the extremely fast response, and the oversensitivity on the controls. There were no favorable features. Special piloting techniques consisted of bracing the arm as well as possible to try to prevent motions of the vehicle being transferred into the control stick.

PILOT E   PR = U7

This particular configuration was oversensitive. Response characteristics were good, but the control sensitivities were so high I had to spend all my time trying not to overcontrol. The task could not really be performed in the normal manner.

CASE 350 (Continued)

Air-taxi-around-the-square was just a slow careful process. I was not able to perform it in a normal manner because of the extreme sensitivities. Response to control inputs was good, but the sensitivities were too high. There was no problem with the heading.

Turning-over-the-spot - no problem with the attitude. Ninety-degree crosswind turns could be performed - same problem, just oversensitive. Precision hover - some disturbances in pitch attitude, but the excess sensitivity overrode everything. It could hover all right if one were content to bounce around, particularly in pitch. I think it would be marginal to land. Quick stops - no further comments.

Overall Evaluation

The objectionable features - oversensitive in pitch and roll. Response characteristics were good and made the machine controllable, but performance was really inadequate for the mission.

PILOT F PR = U7

The system had extremely high, fixed sensitivity and resulted in a PIO tendency in more energetic maneuvers such as a quick stop where one might want to attain a fairly steep attitude in pitch or bank, especially pitch. I felt just about ready to excite a PIO, and very possibly in a larger excursion one could get into a PIO and lose control of the aircraft or at least structurally damage it. On my quick stop I did get into a little bit larger attitude change than in any other maneuver, and it took extreme concentration to keep from going into a PIO due to a very high response of the vehicle to the stick. But when able to control the vehicle at real small inputs without exciting PIO, the aircraft was quite maneuverable. The ride was not smooth due to the constant small-amplitude, high-frequency oscillation of the vehicle, especially in the pitch mode and occasionally in the lateral axis.

The tracking maneuvers and various tasks could be performed fairly accurately and predictably, although requiring a fair amount of pilot compensation in order to try to control the tendencies toward PIO and overcontrol. If one put any inadvertent large inputs into the stick, it would certainly result in an extreme aircraft reaction very fast and probably an extreme attitude. The air-taxi-around-the-square - the ability to initiate motion, once I got used to the system, was reasonably good.

When I could finally tailor my inputs down to a small enough value and keep from overcontrolling, I could hold a preselected rate of movement. But it was easy to overcontrol and get off the rate although I could correct back reasonably well. Ability to stop precisely and come to a hover at the corners was quite good. Excessive attitude changes were not required, nor were they desired, because that was when I could get into more of a PIO and possibly lose control.

Ability to remain within ground-track limits also was quite good. Control feel was much too sensitive. I just couldn't put a small enough input into the stick and, with the pilot in the control loop, there was a feedback and a constant motion around the pitch axis. If I could trim the aircraft out and take my hands off, this motion

would stop. But, of course, the pilot had to be in the loop and this was what seemed to continually feed back into the control system and vehicle response.

Control forces were certainly very light and pleasant. Deflections were very minimal due to the extremely high sensitivity of the system. Trimmability - I just couldn't trim it up to where I could take my hands off for any period of time due to the extreme sensitivity to small control inputs. Response to control inputs in pitch and roll was much too high in addition to the sensitivities. Ability to hold heading was good.

Turns-over-the-spot - ability to remain over the spot was quite good. It was reasonably easy to compensate for the wind effects in pitch and roll; and not much of an attitude change was required, or if it was required it was easy to compensate for. Ability to initiate the turn rates, stabilize and hold on preselected turn rates, and stop on a preselected heading was good.

In the 90-degree crosswind turns into the wind, the time to accomplish the maneuver was not excessive. Once I got used to this special pilot control technique, I didn't feel there was too much of an overshoot or undershoot tendency. Ability to establish heading and position over the spot was average. Control activity - much too much in frequency. The amplitude was very, very small and control power was too high. Precision hover - ability to establish and maintain a basic position over the ground and to maintain altitude was quite good. However, it was not a smooth maneuver.

There was continual movement, especially in the pitch axis and a little bit in the lateral, due to the pilot in the loop completing the feedback. Regarding the ability to hold a reasonably precise position, it was quite good. With concentration and proper piloting techniques, it was adequate for vertical landings. Wind did not seem to affect it too much and I think the maneuver was feasible as long as the pilot used caution.

Quick stops were performed reasonably well. Excessive attitudes were not required. Ability to hold a heading and the altitude was good. Again it wasn't a real smooth maneuver but this was the place where, with a little bit steeper attitude than for normal hovering and tracking maneuvers, I felt that I was just about in the PIO situation. It was starting to excite and diverge and it took considerable pilot attention and concentration to keep from letting this situation progress to a worse condition. Directional and height dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features - supersensitivity of the aircraft response to small control inputs and the inability of the pilot to maintain a smooth constant attitude. In the quick-stop maneuver, there was a tendency to enter a PIO maneuver as attitude changes got larger.

Favorable features - if one could tailor his inputs and damp out pilot inputs to the stick, the system basically was fairly maneuverable in order to accomplish the task outlined here.

CASE 350 (Continued)

Special piloting techniques were required in order to minimize the amplitude of the pilot inputs and to try to damp out the feedback that resulted from the pilot being in the control loop.

CASE 351

$X_u = Y_v$	$= -0.05$	$M_\delta = L_\delta$	$= 0.300$
$M_u g = -L_v g$	$= 0.33$	λ	$= 0.132$
$M_q = L_p$	$= -2.933$	ω_n	$= 2.036$
$M_\theta = L_\phi$	$= -4.372$	ζ	$= 0.700$

PILOT D PR = A5

This particular configuration was quite stable and response was very slow. Inputs were heavily damped in all axes.

On the air-taxi-around-the-square, it took considerable stick movement to initiate the movement. Then the stick had to be held in a particular position to maintain that rate, requiring either holding the fairly heavy force or trimming it out. There were no particular problems in establishing rearward movement because of the slow response. Once the vehicle got off the track or speed, it was difficult to restabilize because of the slow response.

Pitch and roll attitude changes were not excessive. It maintained the ground track fairly well. Control feel - forces appeared high because it was necessary to hold the stick out almost to full deflection on some of the maneuvers. Response was too slow in pitch and roll. Sensitivity was also too low.

Turns-over-the-spot worked out fairly well. It was difficult to be very precise because of the slow response in pitch and roll. There were no problems on turn rates and so forth. Crosswind turns - pretty fast. It did undershoot on the first one.

Precision hover worked out quite well. Once established over the spot it was almost a "hands-off" type maneuver. Vertical landing, because of the slow response or lack of control power, would be undesirable here. Quick stops - the attitude changes required in these maneuvers did not reach the limits. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features were the slow response and large stick travel needed to fly. Favorable features - extremely stable.

PILOT E PR = A5

Control response was satisfactory but the control power, particularly in pitch, was not large enough; e.g., several times the simulator hit the stops in pitch on the quick stop.

The control sensitivities were too low. Air-taxi-around-the-square - the ability to initiate motion was satisfactory except that the control displacements required were too large. I could stabilize and hold a preselected rate of movement, and could stop precisely.

Attitude changes were quite large but, because of the control response characteristics, one didn't hesitate to use very nearly full control and large attitudes. The control forces were somewhat bothersome because of the large deflections required, but there was no problem trimming. I had a little problem holding heading, particularly on the first part of the square. It seemed to wander a bit in heading.

Turn-over-the-spot was not a problem. I did notice that it hit the yaw control stops several times, but I think the rates were adequate to do the job. Ninety-degree crosswind turns - very nearly full lateral control was required to come around the corner, so the lateral control power was too small.

Precision hover - no problems with external disturbances. There was a little problem in being precise because of the large control deflections required to generate any motion. It certainly was adequate to land. Quick stops - longitudinally, the simulator ran into the stops trying to get moving.

Large attitude changes were required but I did not hesitate to use them. Heading and altitude were okay. Control motions - large deflections were required but motions were slow. Secondary dynamics - no problems.

Overall Evaluation

Objectionable features I've outlined. The characteristics were such that I could do the job with a moderate amount of concentration or compensation.

PILOT F PR = A2-1/2

I think this control system can be described best as sluggish but predictable. It was a fixed-gain control system.

Air-taxi-around-the-square - as long as one was satisfied to put in a control movement and wait a little while for it to take effect, he would be pleased with this control system. It took time to initiate a motion. It was not very responsive, but I could initiate moderate rates and stabilize them and hold preselected rates as long as they were not very high rates.

Ability to stop precisely and come to a hover at a corner - unless one used proper judgment, he would have a tendency to overshoot or undershoot. It was difficult to stop precisely because of the sluggish response of the vehicle. Excessive attitude changes were not required as long as one would accept slower rates of movement. Ability to remain within the ground-track limits was quite good. Control feel was sluggish. Forces were adequate. Deflections were not excessive. Trimmability was good.

Response to control inputs in all axes, especially lateral, was sluggish. Sensitivity was low. Ability to hold headings was good. In the turns-over-a-spot, ability to remain over the spot was above average. Attitude control was easily accomplished. Ability to initiate turn rates was good. Ability to stabilize and hold preselected turn rates was good, as was stopping on a preselected heading. Ninety-degree crosswind turns were a little slower than average because of the sluggishness of the vehicle, but it seemed that the vehicle performed them in an adequate manner. There were very few overshoot and undershoot tendencies, as long as the pilot led the maneuvers properly. I think an average pilot would have no difficulty leading these maneuvers properly.

Ability to establish a heading in a position over the spot was adequate. Control activity did not require excessive displacements for this maneuver. Control power seemed low due to the sluggish response of the control system. Precision hover, once established, was very easy to maintain. Attitude and angular rates in position were all precisely controlled, and it was excellent for a vertical landing. Control activities were minimal. It did have some wind effect, but I think a little less than average. It presented no particular problem in compensating for the winds during the turns and hovering maneuvers.

Quick stops - there was a tendency, with the sluggish response of the vehicle, not to get much of a forward movement across the ground. Because of the slowness of response in the vehicle, there was a tendency to overshoot the intended spot. Excessive attitude changes were not required as long as I gave the vehicle time to slow down or accelerate or do whatever I wanted it to do. Ability to hold altitude and heading was good. Control motions were not excessive especially if I gave the vehicle time to respond. Directional dynamics did not affect the problem.

Overall Evaluation

The objectionable feature was the sluggish response of the vehicle to control inputs. The favorable feature was the ability to attain desired rates. The vehicle performed in a predictable manner; however, it was very sluggish. Special piloting techniques were not required as long as a person was content to live with the sluggish response and was willing to give it time to respond and react.

CASE 352

X_u	$= Y_v$	$= -0.05$	M_δ	$= L_\delta$	$= 0.450$
$M_u g$	$= -L_v g$	$= 0.33$		λ	$= 0.132$
M_q	$= L_p$	$= -2.933$		ω_n	$= 2.036$
M_θ	$= L_\phi$	$= -4.372$		ζ	$= 0.700$

PILOT D PR = A5

This particular configuration was quite stable. It was a little slow in roll. Pitch seemed satisfactory; kind of masked by the slow response in roll. There was quite a bit of stick activity in trying to execute precise maneuvers. Both pitch and roll appeared damped. On the air-taxi-around-the-square, there was no difficulty in initiating motion and holding the rate of movement. Precision maneuvers and hovers in the corners required a lot of stick activity. Sideways movement worked out okay. It stayed fairly well within the ground track. Control feel, forces, and deflections - the slow response in roll required a lot of stick activity to execute the movements and motions.

On the turn-over-the-spot, again there was a lot of stick activity in pitch and roll, more so in roll. Turn rates and so forth were satisfactory. Crosswind turns - time was not a factor. Overshoot and undershoot - no problem here. There was a lot of control activity again. Precision hover, after coming to the stop, worked out pretty well. Stick activity was not so much a factor here. And as far as a vertical landing goes, there should have been more lateral control power and more sensitivity on the controls.

Quick stops - no problems here. It worked out pretty well going forward and sideways into and with the wind. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - a lot of stick movement was required to perform precise maneuvers with this vehicle. Response was quite slow in roll; pitch was a little slow but marginally satisfactory. Favorable features - it was a stable machine and, other than requiring a lot of work flying it, fairly comfortable.

PILOT E PR = A2-1/2

This configuration was very pleasant. The only thing that bothered me was that the control sensitivity was a little low. The control deflections required to perform the task were larger than I would have liked.

On the air-taxi-around-the-square, moderate attitudes were required, but there was no problem generating them. There were no external disturbances. The

only complaint was that control deflections were large. Response to control inputs was excellent. Sensitivities were low. Both pitch and roll were the same.

Turning-over-the-spot - no real problem. Also, there was no problem with the attitude turning into or out of the wind. Crosswind turns - the control displacement required was a little large. Precision hover - no problem with external disturbances.

Position and attitude could be maintained precisely. It certainly was adequate to land. Control activity was small. Quick stops - I could stop as quickly as I liked. Attitudes were large but not excessive; it was just that the control displacements were large. There were no other problems. Secondary dynamics - no comments.

Overall Evaluation

It was controllable, acceptable, and satisfactory. The only complaints were the low sensitivity and the larger than optimum control deflections required.

PILOT F   PR = A2

This was an excellent control system. It gave the pilot a high degree of confidence in being able to do pretty much what he wanted with the aircraft. The only consideration that might degrade it somewhat was a slight sluggishness in response, or lack of quickness in response. It was a big-airplane-type feel. However, the precision with which the aircraft could be maneuvered was very desirable. It had fixed sensitivity.

In the air-taxi-around-the-square, the ability to initiate motion was good for predetermined rates. It was slightly sluggish from the time I put in the control input until the aircraft changed attitude. It took a little bit of time for the motion to generate; a little bit more than in some other systems. Ability to stabilize and hold preselected rates of movement was very good. Ability to stop precisely and come to a hover at the corners was excellent. Attitude changes were not excessive in pitch and roll. Ability to remain within the ground-track limit was very good.

Control feel, forces, deflections, and trimmability were all good as was the response to control inputs, other than the comments already made about the sluggishness in response. It wasn't quite as sensitive to control inputs as some people might like, but the ability to hold heading was excellent. Attitude control in pitch and roll was excellent. Ability to initiate turn rates was very good as was the ability to stabilize and hold preselected turn rates and to stop on preselected headings.

In the crosswind turns into the wind, the time to accomplish the maneuver was normal There was less than normal undershoot and overshoot tendency. Ability to establish headings and hold position over the spot was very good. Control activity was minimal and control power seemed adequate. It was easy to establish and maintain precision hover. There were very minimal wind effects, and it was excellent for vertical landing. Control activity was very minimal for hovering maneuvers.

CASE 352 (Continued)

Quick stops - actually a good speed into the wind was obtained. It took just a little bit longer time than some other systems for attaining a given airspeed over the ground; however, I do not say it degraded the quick-stop maneuver. As far as I was concerned, the maneuver could be accomplished quickly enough. Excessive attitude changes were not required. Ability to hold heading and altitude was very good. Control motions were not excessive. Secondary dynamics did not seem to enter into it.

Overall Evaluation

Slight objectionable features, which were very minor, would be the slight big-aircraft feel and slowness in response of the vehicle to aircraft control stick movement. Favorable features - it was a very smooth, very precise, and very predictable control system. Special piloting techniques were not required.

CASE 352 (RERUN)

$X_u = Y_v = -0.05$ $\quad$ $M_\delta = L_\delta = 0.450$

$M_u g = -L_v g = 0.33$ $\quad$ $\lambda = 0.132$

$M_q = L_p = -2.933$ $\quad$ $\omega_n = 2.036$

$M_\theta = L_\phi = -4.372$ $\quad$ $\zeta = 0.700$

PILOT E $\qquad$ PR = A4

In general, I really didn't like flying this configuration because it seemed to be very sluggish, or, more accurately, it required large stick displacement to generate the required attitudes. I was always holding a reasonable amount of force during the maneuvers. Another major complaint was that it seemed to be hard to get started moving, but once moving it seemed to be hard to get stopped. It almost appeared to me that there was no tendency to roll back out for lateral or longitudinal velocity.

In the air-taxi-around-the-square, the ability to initiate motion was poor and then it was a little difficult to stabilize. It tended not to increase extremely rapidly, but it certainly wasn't stable. Stopping it was less than precise. It seemed to consistently overshoot. Large attitude changes were required to generate and stop the motion. It could remain within the ground-track with no problem. Control forces tended to be high because the deflections used were large. Response to control inputs was good in both axes. Sensitivities were low in both axes.

Turning-over-the-spot caused some difficulty with attitude control as it came around. This, coupled with the large deflections required, cut down the precision with which one could remain over the spot. Ninety-degree crosswind turns - control activity was not desirable. I had to use large inputs and hold large forces to come around the corner. There was a small tendency to overshoot. Precision hover - there was difficulty with the attitude control coming around, mainly because of the large deflections required to take out the wind effects. So the precision was less than desirable. It certainly was adequate for landing.

Control activity - large deflections required. Quick stops - could stop quickly but it required large attitudes and very large stick deflections and forces. Secondary dynamics - no problem.

Overall Evaluation

The objectionable feature was a general feeling that the control was sluggish. Large deflections were required for the desired attitudes, and the vehicle was hard to start in motion and difficult to stop. It was controllable and acceptable but unsatisfactory. Certainly these deficiencies would warrant improvement. The performance was adequate. It had some minor but annoying deficiencies and needed improvement. The performance was not adversely affected since one could accomplish the task with no problems.

CASE 353

$$X_u = Y_v = -0.05 \qquad M_\delta = L_\delta = 1.350$$

$$M_u g = -L_v g = 0.33 \qquad \lambda = 0.132$$

$$M_q = L_p = -2.933 \qquad \omega_n = 2.036$$

$$M_\theta = L_\phi = -4.372 \qquad \zeta = 0.700$$

PILOT D PR = A4

This particular configuration was quite easy to fly. Response seemed pretty good. both in pitch and roll. The control sensitivities were a little too sensitive, both in pitch and roll. The vehicle could be trimmed hands off. It was real smooth. However, stick inputs caused a jerky movement of the vehicle.

Air-taxi-around-the-square - motions in each direction were easy to initiate and easy to hold. Precise hovers worked out very well at the corners. Pitch attitude and roll changes were not excessive. There was no particular problem remaining within the ground-track limits. Control feel was just a little too sensitive in pitch and roll. Forces and deflections were satisfactory; deflections were very small. Response and all that seemed very good.

Turns-over-the-spot also worked out very well. Attitude control was good, and turn rates, etc. were good. Crosswind turns worked out pretty well; they were real rapid. I may have overshot one. There was not a whole lot of control activity. Precision hover - jerky movement both in pitch and roll for the minor corrections needed. It could be trimmed hands off and it was very smooth.

Quick stops worked out very well. Attitude changes weren't excessive; control motions were satisfactory. Secondary dynamics did not affect the evaluation.

Overall Evaluation

The objectionable feature of this particular vehicle was that it was a little too sensitive in pitch and roll. Hands off, it was stable and flew real well. Favorable features - easy to fly and quite stable. Special piloting techniques would be to have it trimmed as much as possible so that it would not require stick inputs.

PILOT E PR = A3

The sensitivities were fairly close to what I desired. The roll was just a little bit high and the pitch was about right. However, it seemed to have a lot of pitch attitude response to external disturbances, and at times I felt there was an oversensitivity in pitch.

The air-taxi maneuver - the attitude changes required to generate velocities were a little larger than I'd have liked, but really not in this case. I think I'm speaking more of the quick stop there. So one could remain within the track limits as well as one wanted to work at it. There were no problems with trim. The control response was best in roll. It seemed a little slower to me in pitch, but both were quite acceptable. Sensitivities were always a bit high. Pitch was about right. There were no problems with heading.

Turns-over-the-spot - could remain over a spot without any difficulty. Attitude control was not a problem. No other comments. Ninety-degree crosswind turns - no problems. Precision hover - there was a little annoying disturbance feeding through the pitch attitude, but it was no real problem to control. It was adequate to land. Control activities were small, just about right.

Quick stops - perhaps trimming into the wind, plus the attitude required to move forward, was a bit too much. I could stop as quickly as I wanted. Attitude changes - no complaints.

Overall Evaluation

The objectionable feature was disturbance in pitch attitude, which appeared to me to be an external disturbance. At times it felt like an oversensitivity in pitch, but I don't think so. The attitudes were not a problem in turning in and out of the wind, but I did notice in the quick stop that I didn't like the attitude required to generate the velocity; it was too large. So it was controllable, acceptable, and I think it was clearly adequate for the mission in spite of the disturbance in pitch.

PILOT F PR = A2-1/2

This was a pleasant, rather fast-acting control system, fairly responsive to the pilot's desires. But there was one characteristic that was a little bit disconcerting. It had a tendency to wander about the trim point of the stick. It required constant monitoring and spurious small adjustments of control inputs to maintain a real stable, steady hover. This characteristic was pretty well masked over in dynamic maneuvers. Control sensitivity was fixed for this evaluation.

In the air-taxi-around-the-square, the ability to initiate motion in each direction was quite adequate. I could stabilize and hold preselected rates of movement better than average. Ability to stop precisely and come to a hover at the corners was quite easy as long as I anticipated the wind effects. I think this system was less sensitive than most to the wind effects.

Attitude changes to compensate for different winds were quite minor. Ability to remain within the ground-track limits was good. Control feel was good, forces were to this pilot's liking, deflections were not excessive, and the aircraft could be trimmed up fairly well. Response to control inputs in all axes, expecially roll and pitch, was

characterized by good response, quick acting. Sensitivity was fixed for this evaluation. It made the system very responsive to the pilot's control inputs. Ability to hold heading was good.

In the turns-over-a-spot, the ability to remain over the spot was good. Wind probably affected the system a little less than average. Attitude to control pitch and roll, in order to hold a spot, was accomplished easily with not too much pilot attention. Ability to initiate turn rates, stabilize and hold preselected rates, and stop on preselected headings was good.

In the 90-degree turns into the wind, the time to accomplish the maneuver was very nominal. Overshoot and undershoot tendencies were nonexistent. Ability to establish heading and position over the spot was very good. Control activity was normal, and control power seemed very adequate. I could easily establish and maintain a precision hover, with the exception that I did have a random movement about the trim point. It was not too disconcerting but did require some additional pilot workload, attention to attitude, and occasional pilot input to correct the attitude as it wandered about. The system was very adequate for a vertical landing.

Control activity in the precision hover was normal. When I say normal for precision hover, I mean very little stick activity was required. Quick stops were accomplished as fast as I preferred. Excessive attitude changes were not required. Ability to hold heading and altitude was good. Control motions required for the quick-stop maneuver were normal and nominal. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

The objectionable features - it might tend to be just a little bit oversensitive to control inputs. I didn't find it too much, but others might feel it was somewhat more objectionable. The wandering tendency about the trim also was a minor objection.

Favorable features - it was responsive, fast acting, and smooth. The pilot gained quite a bit of confidence in being able to maneuver the aircraft as he desired, without overcontrolling or losing control. No special piloting techniques were required.

CASE 354

X_u	$= Y_v$	$= -0.05$	M_δ	$= L_\delta$	$= 4.050$
$M_u g$	$= -L_v g$	$= 0.33$		λ	$= 0.132$
M_q	$= L_p$	$= -2.933$		ω_n	$= 2.036$
M_θ	$= L_\phi$	$= -4.372$		ζ	$= 0.700$

PILOT D PR = U7

This particular configuration was very sensitive in pitch and roll. Response was very fast making it difficult to control. There was lack of stability in pitch and roll so that hands-off flying was impossible. I was unable to trim into a stabilized condition. I could only remove my hand briefly from the stick without losing control of the vehicle.

Air-taxi-around-the-square - easy enough to initiate motion in each direction. Holding the preselected rate of movements, there was a lot of vehicle activity and oscillations both in pitch and roll. Hovers at the corners worked out okay, but here again the vehicle was shaking quite a bit. Pitch and roll attitude changes were not excessive. Ground track was within acceptable limits. Control feel was too sensitive, forces okay, deflections very small. Response was too quick in pitch and roll. Sensitivity - too sensitive.

Turns-over-the-spot worked out fairly well. Pitch and roll attitudes control - here again, a lot of oscillations in both axes. Turn rates - no comment, okay. Crosswind turns - pretty fast, didn't overshoot or undershoot. Control activity - here again, there was a lot of control activity because of the quick response of the vehicle and the oversensitivity. Precision hovers worked out pretty well. Here again, the vehicle was in constant oscillation in pitch and roll.

Quick stops - forward okay; sideways, quick stops with and into the wind worked out okay. Same comments on pitch and roll oscillations as previously. Control motions were very small. Secondary dynamics did not affect the evaluation.

Overall Evaluation

The objectionable features were oversensitivity, too fast a response, and lack of stability. No mentionable favorable features. Special piloting techniques were to try to exert as little pressure as possible on the stick. When possible, the stick was trimmed out but this was very difficult because of lack of stability.

PILOT E PR = U8

This configuration was oversensitive in both axes. One could control it alright with a good deal of attention. Response characteristics were basically excellent so

CASE 354 (Continued)

that with a little effort to control inputs on the stick, I could do the job, but it was much too sensitive.

Air-taxi-around-the-square - with the sort of sensitivity that this model had, it was a matter of using extreme caution to avoid overcontrol. I could easily get into hitting the stops several times with abrupt inputs. So with that in mind, I could do the square reasonably precisely, but the attention level was very high. There were very small high-frequency inputs. There were no problems with trimming.

Control responses were hard to see amidst all this overcontrolling, due to the high sensitivities. The responses would have been quite nice with reasonable sensitivity. Turning-over-the-spot was possible - no outstanding problems. Ninety-degree turns - same comments. One could do them but the attention level was extreme.

Precision hover - I think I could have landed it with a high attention level. The quick stops - one could get into problems if one tried any large inputs quickly. Providing I used the caution required, I could do the quick stops adequately.

Overall Evaluation

The overall objection was oversensitivity. Both axes seemed very much the same. I think if one had any other duties to perform and got into a position where he had to put in rapid inputs, then he could overcontrol rather severely. It was certainly controllable but with difficulty. Substantial pilot effort was required to retain control.

PILOT F PR = U9

This control system was evaluated with a fixed sensitivity. Generally, the system was extremely sensitive, very fast reacting, and was on the verge of PIO at all times, especially in the pitch mode. I made a conscious effort to try to damp it out. I braced my elbow against my knee to try to keep from feeding back vehicle motions into the stick. It took considerable attention to make sure these motions were damped out. I still felt that any time it could start getting in phase with the feedback into the aircraft, creating a PIO which would probably structurally damage the aircraft or result in complete loss of control. For some reason it didn't seem to be as bad in the lateral axis although it seemed the response to a lateral input of the stick was just as fast as it was to a pitch input. Whether it was the simulator or some difference in the pitch and roll control systems of this particular system I don't know, but the pitch PIO seemed to be more of a problem than the lateral PIO. This condition existed throughout the evaluation.

In the air-taxi-around-the-square, the ability to initiate motion was adequate in each direction; however, it was very difficult to stabilize and hold preselected rates of movement because of the constant trial-and-error type of control inputs required. I would put in a little bit of control input and it would be too much, so I was constantly putting in extremely small but very frequent control inputs to make the vehicle perform in the maneuver desired. Ability to stop precisely and come to a hover at the corners was reasonable. I shouldn't say precisely because the vehicle always had some sort of motion from the constant control inputs and the vehicle response and that caused another control input; so it was always in motion and certainly wasn't stable. This applied to the entire evaluation.

CASE 354 (Continued)

Excessive attitude changes were not required. In fact, it was very difficult to refine control input enough to maintain the attitude desired. Ability to remain within the ground track was fairly good. Control feel was much too sensitive. The forces were light. Deflections were almost not required because the vehicle response to small control inputs was very rapid and very quick. It was rather difficult to tell whether one could trim it up or not; it was almost like having a zero trim point all of the time. Response to control inputs was much too sensitive about the lateral and pitch axes. Ability to hold heading was good.

In the turns-over-the-spot, the ability to remain over the spot was good. Attitude control - the control was able to be maintained but with very high pilot workload. Ability to initiate turn rates was good. Ability to stabilize and hold preselected turn rates and stop on preselected headings was good. Ninety-degree turns into the wind were accomplished in the normal amount of time. Overshoot or undershoot tendencies weren't bad; I think I hit the spot reasonably well. I could roll out on the heading and fairly well on the position that I desired. However, control activity was high. Control power was probably too high, resulting in a lot of workload to keep the control inputs small and to keep from entering into a PIO maneuver.

I could generally establish and maintain a hover in a general area quite easily; however, the vehicle was in constant motion in pitch and roll, with frequent control inputs both inadvertent and advertent. Attitude and angular rates were not noticeable. It was not very sensitive to wind. One could make vertical landings with this system, although not as well as if the aircraft control system was not as supersensitive. Control activity, of course, was very high, very frequent, but very small amplitude.

Quick stops were initiated and performed as fast as I liked. Excessive attitudes were not required. Ability to hold heading and altitude was good. Control motions were again very frequent but of small amplitude. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features were the extremely fast and frequent response to control inputs, the inability to hold a constant attitude with the control system, and the very strong and constant tendency to enter a pitch PIO maneuver.

Favorable features - very few, if any. I guess it might be favorable that I didn't crash with such a tendency towards PIO. Special piloting technique was required, and it required pilot attention to make sure that I did not induce PIO by concentrating on very small, smooth control inputs. The reactions of the vehicle to pilot control inputs resulted in too quick and fast a vehicle response which slipped back into the control system, resulting in a very rough ride and constant pilot attention to prevent PIO.

CASE 355

$X_u = Y_v = -0.05$ $\qquad M_\delta = L_\delta = 6.075$

$M_u g = -L_v g = 0.33$ $\qquad \lambda = 0.132$

$M_q = L_p = -2.933$ $\qquad \omega_n = 2.036$

$M_\theta = L_\phi = -4.372$ $\qquad \zeta = 0.700$

PILOT D PR = U9

For this particular configuration, the response was extremely fast. It felt like there was a complete lack of stability, and the sensitivity was very high. Frequency was such that the vehicle would shake and cause the stick to shake the vehicle itself. Also, there was a tendency, because of the very light feel on the stick, to induce a PIO which could be controlled.

Air-taxi-around-the-square - initiating the motion caused a continuous oscillation which was more noticeable in pitch than in roll, making it difficult to initiate motion and hold any selected movement. This was true in both directions. Most attention was applied to just flying the vehicle. Precise hover at the corners was nonexistent. Attitude changes weren't excessive. The vehicle was continuously oscillating and shaking around; it was very uncomfortable.

It did stay fairly well within the ground-track limit. Control feel - overly sensitive. Forces were light, deflections very small. Response was too sensitive in pitch and roll; more so in pitch the way it felt. Sensitivity was too high. Turn-over-the-spot - here again, same comments on attitude control of pitch and roll. The crosswind turns worked out fairly well. The time was not excessive. No overshoot or undershoot tendency was noted.

The precision hover - was able to stay over the spot. However, attitude was constantly changing. Vertical landing - wouldn't want to attempt it in this particular vehicle. Quick stops worked out okay. Here again, excessive attitude changes weren't required. Control motions were very small but there were continuous pulsations and oscillations as mentioned previously. Directional and height dynamics were good.

Overall Evaluation

Objectionable features - extremely fast response and overly sensitive. It was extremely difficult to fly due to a lack of stability, and the pilot had to stay right there or he would lose it. No favorable features were noted. It was very marginal. It gave the feeling that losing control of the machine was possible because it might shake apart.

PILOT E PR = U9

The sensitivities in pitch and roll were so high that the vehicle was just marginally controllable. I could control it with a good deal of adaption by taking things very gently, but any sort of abrupt motion would cause me to go quickly from stop to stop.

The air-taxi-around-the-square was possible to do with a good deal of care, but stabilizing the rates of movement wasn't really possible. The machine could be hovered but, once again, I was marginally in control. No large attitude changes were required or attempted so I could follow the ground track reasonably well.

Control deflections were very small. The responses to the control inputs were pretty hard to see because there was a constant high-frequency, low-amplitude oscillation in both axes due to inadvertent motions of the hand throughout. It's my guess it would have been all right with the proper sensitivities.

The turn-over-the-spot and the crosswind turns - no particular comments except I could do them. Precision hover and quick stops - no comments that haven't been made already. Secondary dynamics - no comments.

Overall Evaluation

Objectionable features - fantastically high sensitivity in both pitch and roll made control difficult. Favorable features - none. Special piloting techniques - one must move his hand as little as possible.

PILOT F PR = U9

This control system was supersensitive and very rough. I don't know whether it was the small gusts from the wind that excited the control system, the pilot in the loop, or what, but the aircraft was continually responding to some sort of influence. Whatever the reason, it gave me a feeling of insecurity. It made me feel that at any moment I might lose control of the aircraft unless perfectly trimmed up. On takeoff, not knowing the trim conditions, one could probably damage it or crash it just trying to get it airborne. Once in the air, I was able to adapt and keep the aircraft under control to accomplish the given tasks. However, all during this time I had an insecure feeling. It required complete attention to maintain an attitude because if I let go of the stick the aircraft would have gotten out of control and probably crashed. It was a fixed-gain sensitivity.

In the air-taxi-around-the-square, the ability to initiate motion was average. I was able to do it. It was a rough ride throughout and this, of course, contributed to the concern of the pilot. The ability to initiate motion and stabilize at reasonable rates of movement was not bad. I'd say initiating motion was good. Ability to stabilize and hold a preselected rate of movement, because the motion of the vehicle was below average, was very difficult. Ability to stop precisely and come to a hover at the corners also was below average because of always putting in too much and having to take out corrections. The aircraft was bouncing around and I didn't have the feeling of firm control over the aircraft.

CASE 355 (Continued)

Excessive attitude changes were not required because of the quick and immediate response to many, many different sources, I guess. I was not aware of the wind sensitivity as such in terms of having to put the control over into the wind. I was unaware of any large movements, but there were almost constant stick corrections to maintain an attitude. Control feel was hypersensitive. Forces and deflections were not noticeable because they were all around some given trim point. Response to control inputs - hypersensitive. Ability to hold heading was good.

Turns-over-a-spot - ability to remain over a spot generally was not bad. Attitude control - with considerable pilot attention, pitch and roll attitude could be controlled. It did not become excessive due to the constant attention that I gave to that task. Ability to initiate turns and stabilize and hold preselected turn rates, and stop on a preselected heading, was good. All during this time, I didn't have to worry about the rudder response because that was good. Almost all attention was devoted to just maintaining a hovering attitude. Ninety-degree crosswind turns - time to accomplish maneuver was not excessive; there were no serious overshoot or undershoot tendencies. Ability to establish heading and position over the spot worked out fairly well on the two maneuvers attempted.

I had an overabundance of control power. Control activity was excessive in terms of constant small inputs to the stick to counteract the motion of the vehicle. Precision hover - on motion over the ground, I was able to maintain a relatively precise hover. However, the aircraft was going through constant pitch and roll motions even though there were almost no translations. The attitude was relatively constant with turbulence affecting the attitude, but I didn't have a heeled-over attitude into the wind in order to maintain a position over the ground. It would have required considerable attention but the aircraft could have made a fairly decent vertical descent and landing.

Control activity for hover and all maneuvers was considered excessive only in terms of frequency, not in terms of amplitude. Quick stops were accomplished at a reasonable rate. Excessive attitude changes were not required. Heading and altitude were held within reasonable limits. Control motions in order to perform the maneuver itself were not excessive. Secondary dynamics did not seem to be a factor.

Overall Evaluation

Objectionable feature - it was violently objectionable in terms of smoothness of ride. The aircraft was continually bouncing around, requiring constant stick inputs to control the attitude. I didn't see any favorable features. I think that a very short period of inattention by the pilot, such as head in the cockpit or releasing the stick, probably would have resulted in aircraft attitude becoming uncontrollable or at least in a condition requiring extreme action to recover the vehicle.

Special piloting techniques - I had to really concentrate on the attitude of the aircraft, continue to monitor the attitude, and put in very frequent stick inputs to control it.

CASE 356

$X_u = Y_v = -0.05$ $\qquad$ $M_\delta = L_\delta = 0.300$

$M_u g = -L_v g = 0.33$ $\qquad$ $\lambda = 0.374$

$M_q = L_p = -1.785$ $\qquad$ $\omega_n = 1.044$

$M_\theta = L_\phi = -1.547$ $\qquad$ $\zeta = 0.700$

PILOT D PR = A5

The response was quite slow; sometimes, it would get out of phase with a correction, leading to a slight oscillation or PIO. There was no problem in damping it out.

The air-taxi-around-the-square - no problem initiating motion either forward or sideways. It was difficult to hold any preselected rate precisely because of the slow response of the system and overcorrecting in a lot of cases. Stops at the corners were mediocre. Pitch and roll changes for this particular maneuver were not excessive. It stayed within the ground track fairly well.

Control feel - forces seemed okay. Deflections weren't too great. The response was too slow in response to the controls in pitch and roll. After an input on the controls, the vehicle was slow getting its attitude adjusted back to that desired with opposite stick input. Sensitivities were too low on pitch and roll.

Turns-over-the-spot worked out fairly well. Again, it was hard to hold the precise position because of the slow response of the system. Crosswind turns worked out pretty fast. There were no overshoot and undershoot tendencies. Control activity was moderate.

Precision hover worked out very well, and possibly a vertical landing could be accomplished with this machine. Quick stops - no particular problem here. I did overshoot going sideways with the wind. This was attributed to the slow response of the system. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features were the slow response and low sensitivity. The frequency of the system was such as to induce a PIO, which was easily damped out by the pilot. Favorable features - fairly easy to fly. It didn't appear real stable but if it did diverge, it would roll off or pitch down very slowly.

PILOT E PR = A4-1/2

This configuration was very well behaved, but extremely sluggish. Control sensitivities were a lot lower than I liked, both in pitch and roll.

CASE 356 (Continued)

The air-taxi-around-the-square was not a real problem. Motion could be initiated with a reasonable attitude, except it required large control deflections to do so. It tended to overshoot the spot that I wanted to stop and hover at. The attitudes required were not really excessive in themselves, but the control deflections required to generate the attitudes were very large and I seemed to hesitate to use them. So, it tended to be a little sloppy in the position control. Response to control was excellent in both axes. Sensitivities were much too low.

Turning-over-the-spot - there was some problem of attitude control to turn in and out of the wind. It was a rather "lazy" model to fly and it was difficult to remain precisely over the spot. Ninety-degree crosswind turns - couldn't do the maneuver with the precision that I'd like to see. Precision hover - position was the main problem. There was some disturbance in pitch attitude, and external disturbances tended to slide me around. With the sluggish controls, one tended to do just that, not holding the position accurately. It certainly could be landed.

Control activity - had to use large inputs. Quick stops - tended to have to anticipate a good deal where I wanted to stop. It took some time to generate the attitudes. Control motions were again large and objectionable. Secondary dynamics - no problems.

Overall Evaluation

It was unsatisfactory because of the sluggish response and lack of sensitivity, plus the inability to be precise in position control with some of the external disturbances.

PILOT F PR = A1-1/2

This was a very good control system. It felt solid and predictable, but slightly sluggish; not bad. It had fixed control sensitivity.

Air-taxi-around-the-square - it was not a real light feeling system; therefore, it took a little more stick input and a slight amount of time to initiate a motion. But it was not objectionable, at least not to this particular pilot. Ability to stabilize and hold preselected rates of movement was better than average. Ability to stop precisely and come to a hover was very good. Excessive attitude changes were not required. Ability to remain within the ground-track limits was good. Control feel - it felt solid. Forces were moderate and deflections were not excessive at all. Trimmability was good. Response to control input - slightly sluggish but predictable. Sensitivity was fixed and I liked the response of the vehicle. Perhaps it could have been just a little quicker, but it was not bad at all. Ability to hold heading was good.

In the turns-over-a-spot, the ability to remain over the spot was good. It was less sensitive to wind effects than average. Attitude control was easily attained and maintained. Very minimal pilot workload was required in order to maintain control of the attitude to compensate for the wind effects. Ability to initiate turns, stabilize and hold preselected turn rates, and stop on preselected headings, was good. In the 90-degree turns into the wind, the time to accomplish maneuvers was normal. Overshoot/undershoot tendencies were no problem. Ability to establish heading and position over the spot was good.

Control activity was minimal and control power was adequate. Precision hover was easy to establish and maintain. Attitude and angular rates were not affected significantly by wind, and position was easy to maintain. It was excellent for vertical landings. Control activity was very minimal. Quick stops were accomplished fast enough; just a little bit sluggish perhaps, but not much. Excessive attitude changes were not required. Ability to hold heading and altitude was good. Control motions were not excessive. Secondary dynamics did not enter into it.

Overall Evaluation

The only objectionable feature was a slight sluggishness in response. Again, it was very minor. Favorable features - it was a predictable control system, smooth reacting, easy for the pilot to fly, and required less than average pilot workload in order to monitor the attitude and correct control stick inputs.

No special piloting techniques were required. It was basically very good, but the slight sluggishness made for a little bit more workload than ideal in order to hold given maneuvers. The slight sluggishness of the system made it slightly less than desirable but it was a very good system.

CASE 356 (RERUN)

$X_u = Y_v = -0.05$	$M_\delta = L_\delta = 0.300$
$M_u g = -L_v g = 0.33$	$\lambda = 0.374$
$M_q = L_p = -1.785$	$\omega_n = 1.044$
$M_\theta = L_\phi = -1.547$	$\zeta = 0.700$

PILOT F   PR = A4

This control system was characterized by a very smooth response of the aircraft to control inputs. However, the aircraft response to stick displacement in terms of rates of movement across the ground was very, very sluggish, and this was the major degrading factor. There seemed to be some random movements about trim, but it seemed to be very low frequency and easily compensated for by the pilot; however, it did introduce a small annoyance factor on top of the sluggish response. Control sensitivity was fixed.

In the air-taxi-around-the-square, the ability to initiate motion again was sluggish. After I put a control input in, the aircraft changed attitude fairly slowly but very precisely and very predictably; then, pretty soon, the rate of movement started to build up. Once I got used to this extreme time delay, I could stabilize and hold a preselected rate of movement. Ability to stop precisely and come to a hover at corners was only fair due to the undershoot or overshoot tendencies caused by the time delay between aircraft response and a control input.

Excessive attitudes were not required. Ability to remain within the ground track was within limits. Basically it was pretty good; not outstanding but not too bad either. It was complicated primarily by the fact that if I saw the need for a small correction, it took such a long time for the aircraft to react and correct in its track to a small control input. Control feel was that of a fairly large aircraft. Deflections were moderately large, and trimmability was pretty good except for the low-frequency random movements about trim.

Forces were slightly heavy but acceptable. Response to control inputs, as I stated previously, was too sluggish really. Sensitivities - the aircraft response to control input, in terms of attitude change, was rather pleasant and basically acceptable. In the turns-over-the-spot, the ability to remain over the spot was complicated by the very slow ability of the aircraft to correct to an unwanted movement over the ground. Once I had things pretty well stabilized, it did require fairly low workload in order to maintain position over the ground. Ability to initiate turn rates, stabilize on a turn rate, and stop on a preselected heading, was good. The turning-over-a-spot was basically sluggish. I anticipated to a degree, but when I anticipated a little bit in error it took a fairly long time to correct the unwanted movement.

In the 90-degree crosswind turns, the time to accomplish the maneuver was normal. Undershoot tendencies were present because of the sluggish response of the aircraft to control inputs. Ability to establish headings and positions over the spot was

really quite good, once I was able to anticipate the time delay in the system. Control activity wasn't of a high frequency, but occasionally fairly large deflections or control movements were needed. There certainly was no PIO tendency of any nature, just slightly larger deflections than normal. Control power was adequate. If sluggishness would be decreased by increasing the control power, this would be desirable.

Precision hover, once established, was easy to maintain with the exception of the very low-frequency random movements about trim. However, this introduced a very minor additional workload. It was more than adequate for vertical landings. Control activity basically was minimal. In the quick stops, I could attain a reasonable rate of movement across the ground and into the wind without excessive attitude or stick displacement. Ability to hold heading and altitude was good. Control motions required were not excessive. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

Objectionable features would be the rather sluggish response of the aircraft to control inputs and pilot's desires, the long delay between attitude change and rates of movement across the ground, and low-frequency random movements about a trim position.

Favorable features - it was a very smooth control system in terms of movement of the stick in conjunction with the resulting movement of the aircraft about a given axis. Basically it seemed fairly stable and responsive in a sluggish manner to the pilot's desires, but it certainly gave no feeling of apprehension as far as losing control. Basically I could make the aircraft perform quite well and to the pilot's desires, although not as fast as perhaps I would like.

No special piloting techniques were required except the anticipation of the time delay between the control inputs and aircraft response.

CASE 357

$X_u = Y_v = -0.05$ $M_\delta = L_\delta = 0.450$

$M_u g = -L_v g = 0.33$ $\lambda = 0.374$

$M_q = L_p = -1.785$ $\omega_n = 1.044$

$M_\theta = L_\phi = -1.547$ $\zeta = 0.700$

PILOT D PR = A5

For this particular configuration, response was rather slow, more so in roll than in pitch. The roll seemed to be well-damped. Pitch also was pretty well-damped, but not as heavily damped as roll.

On the air-taxi-around-the-square, initiating forward motion was no problem. Quite a nose-down attitude, though not extreme, was required. Holding a rate of movement was a little difficult because of the slow response. On stopping at the corners - little difficulty there. Excessive attitude changes weren't required in pitch or roll. It stayed within the ground track fairly well. However, precise maneuvers were somewhat restricted because of the slow response.

Control feel, forces, and deflections – in the air-taxi, deflections weren't excessive. Forces felt okay. Response in pitch and roll was too slow. Sensitivity also was too low. On turns-over-the-spot, holding precise position over the spot presented a problem. Turn rates and so forth were satisfactory. Crosswind turns – time was not excessive, fairly rapid.

Hovers – didn't overshoot or undershoot. Control activity – well-controlled movements were required, especially coming into the hover. Precision hover – once the position was established it could be held fairly well. When it was disturbed, it took a little work to get back to the position desired. Again, due to the slow response, it was difficult to execute precision maneuvers.

Quick stops – forward into the wind, ran out of control. Attitude change may have been a little excessive here. The full travel of the control stick was required. Stops were satisfactory. Directional and height dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features – it was difficult to execute precise maneuvers because of the fairly slow response of the system. Favorable features – a stable machine; other than stability, nothing particularly favorable. Slow response was objectionable and it affected performance. It was difficult to do a precision maneuver with the particular response of this configuration.

CASE 357 (Continued)

PILOT E PR = A4 -1/2

There were several things I didn't like about it. It seemed to require the use of excessive attitudes to get stopped in translation. Particularly laterally, I didn't like it. Control sensitivities were about right in roll but I thought I could use a little more sensitivity in pitch.

Air-taxi – initiating motion required a reasonable attitude and that wasn't bothersome. I seemed to have a little trouble wallowing in roll in the first part of the square pattern. I tended not to be able to stop as precisely as I wanted to, particularly laterally. I tended to overshoot and had to anticipate by a good margin before I could stop where I wanted. The attitude changes, particularly in roll again, seemed excessive; even then, they weren't entirely adequate to stop precisely, so I wasn't happy with the precision with which I could fly the ground track.

Control forces and feel – the deflections tended to be fairly large but didn't bother me too much. The trim was not a problem. Response to the control inputs – no real complaints about the response characteristics. It seemed to have a little bit of overshoot in roll. Turning-over-a-spot – I couldn't remain over the spot as precisely as I liked. Attitude control was the major problem. Large changes in attitude were required to correct position errors, otherwise no problems. Ninety-degree crosswind turns – the maneuver could be performed reasonably well – no complaints. Large control deflections were required, particularly in roll.

Precision hover – I was not too happy with the attitude control. I had to use large changes in attitude. I certainly could land it. In the quick stops, particularly laterally, I tended to have to generate large attitude changes and hold them to get stopped. Heading, altitude – no problem. Control motions were not really bothersome.

Overall Evaluation

I guess the real reason I didn't like it were the large attitudes required; I had to hold them for a long time to get stopped, particularly laterally. Also, it lacked precision in holding position, and sensitivity in pitch was a little low.

PILOT F PR = A2

This was another smooth, desirable, predictable control system, very much to this pilot's liking. Control sensitivity was fixed.

In the air-taxi-around-the-square, the ability to initiate motion and stabilize and hold preselected rates of movement, or to alter the desired rate of movement, was pretty good. Ability to stop precisely and to come to a hover at the corners also was very good. Attitude changes were not excessive. Wind effect was therefore nominal or mild. Ability to remain within ground-track limits seemed to be very good also.

CASE 357 (Continued)

Control feel, forces, deflection, and trimmability were all good. Response to control inputs was adequate. Some people might say it was a little sluggish, but it seemed adequate to me. Sensitivity was fixed and ability to hold heading was good. Turns-over-a-spot and the ability to remain over a spot were above average. Attitude control in pitch and roll was easily maintained by the pilot. Ability to initiate and hold preselected rates of turn and stop on preselected headings was pretty good.

Ninety-degree crosswind turns could be accomplished at a reasonable rate with no undershoot or overshoot tendencies. Ability to establish heading and position over the spot was outstanding. Control activity was minimal and control power seemed adequate. Precision hover was easily established and maintained. Very minor attitude changes and angular rates were required. It was excellent for a vertical landing.

Quick stops were accomplished at an adequate rate. Excessive attitude changes were not required. Ability to hold heading and altitude was very good. Control motions were not excessive. Secondary dynamics did not seem to affect the evaluation.

Overall Evaluation

The only objectionable feature some people might have, which I did not find objectionable here, was a slight sluggishness of the response to the control input. Favorable features – it was a smooth, reasonably fast acting, predictable control system. No special piloting techniques were required.

CASE 357 (RERUN)

$X_u = Y_v = -0.05$ $\qquad$ $M_\delta = L_\delta = 0.450$

$M_u g = -L_v g = 0.33$ $\qquad$ $\lambda = 0.374$

$M_q = L_p = -1.785$ $\qquad$ $\omega_n = 1.044$

$M_\theta = L_\phi = -1.547$ $\qquad$ $\zeta = 0.700$

PILOT F PR = A3

This was a very smooth control system. The aircraft changed attitude very smoothly in response to control inputs; however, there was a very long time delay between the aircraft change and the establishment of the rate of movement across the ground. Also, there was a fairly low-frequency random movement about the trim position of the stick throughout the evaluation. The stick control sensitivity was fixed for this evaluation.

In the air-taxi-around-the-square, the ability to initiate motion was only fair, due to the fairly long time delay. After I put an input into the stick, the aircraft would change attitude very nicely. Then I would sit there a very long time before the aircraft would start moving across the ground in the desired direction. Once I got used to this time delay, the ability to stabilize and hold preselected rates of movement was not too bad. The ability to initiate small corrections to track seemed to improve when I got a little more experience with the system.

Ability to stop precisely and come to a hover at the corners improved as I gained experience again. I was able to predict the response of the aircraft, and actually it was not too bad in terms of being able to guess where the aircraft was going to come to a hover. There was some tendency towards overshoot or undershoot and having to correct back into the desired position. However, attitude changes were certainly not excessive in order to accomplish the maneuver. I think I commented pretty much on the ground-track limits before. They were just fair in terms of being able to remain within the track limits because of the difficulty in introducing small corrections to track. However, it did not have too great a tendency to move out of the line and, if I was able to establish a reasonably good track to start with, the task was fairly simplified.

I felt that the aircraft response to the forces in the stick was very pleasant; slightly on the high side, or heavy side perhaps, but really very pleasant. Deflections at times were probably a little greater than average but not disconcerting. Trimmability was only fair because of the random movements of the aircraft about any given particular trim point. It was really difficult to hit the trim on the nose and it was not a very precise trim situation. Response to control inputs, I'll cover again; pleasant attitude change to control inputs but much too long before the aircraft initiated a movement across the ground. Sensitivity was adequate and ability to hold heading was good.

In the turns-over-the-spot, the ability to remain over the spot was only fair because of the long delay between seeing a need for a correction and the time I was

able to get the aircraft to respond to a control input. There were no excessive attitude changes due to changes of relative wind; however, it did take a fair pilot workload in order to compensate for those changes that did occur. Ability to initiate turn rates, hold preselected turn rates, and stop on preselected headings, was very good. In the turns into the wind, the time to accomplish the maneuver was not excessive. There were relatively minor undershoot/overshoot tendencies due to the lack of the aircraft response to inputs.

Ability to initiate a heading and position over the spot was relatively good. Control activity did not seem excessive. Occasionally I was encouraged to make fairly large control deflections in order to make the aircraft respond a little quicker, but this did not lead into any serious overcontrol or PIO tendencies. As long as control power had no effect on the time delay between attitude change and performance response of the aircraft, control power was adequate.

Ability to establish and maintain precision hover was basically good. There was some fairly low-frequency movement about the trim position which introduced a slight additional workload, but I would not consider it seriously detrimental. It was very adequate for vertical landings. Control activity overall was nominal.

Quick stops were accomplished as quickly as I preferred; excessive attitude changes were not required. Ability to hold heading and altitude was reasonable, and control motions were not excessive. Of course, in the quick-stop maneuvers, due to the long time delay between control input and vehicle response, I did have a tendency to overshoot or undershoot somewhat; this made for a little bit of additional workload in terms of pilot guessing as to what was required to stop. But overall I didn't think that the maneuver was degraded seriously. I think that the pilot soon learned to anticipate the time delay and compensate fairly well for it. Directional and height dynamics did not seem to affect the evaluation.

Overall Evaluation

The objectionable features would be the long time delay between vehicle attitude change and vehicle response to movement across the ground with the fairly low-frequency but nevertheless noticeable random movements about trim position.

Favorable feature was the extremely smooth vehicle response to control inputs in terms of attitude changes, and overall I did have a high degree of confidence in being able to control the vehicle as I desired.

No special piloting techniques were required except consideration of the time delay between vehicle attitude change and vehicle response.

CASE 358

$X_u = Y_v = -0.05$ $\qquad M_\delta = L_\delta = 1.350$

$M_u g = -L_v g = 0.33$ $\qquad \lambda = 0.374$

$M_q = L_p = -1.785$ $\qquad \omega_n = 1.044$

$M_\theta = L_\phi = -1.547$ $\qquad \zeta = 0.700$

PILOT D PR = A6

The response of this particular configuration was too fast both in pitch and roll. The control stick was too sensitive to control inputs. It seemed to fall off rather rapidly in roll. Pitch seemed stable enough. Damping - that was satisfactory in both axes.

Air-taxi-around-the-square - on initiating forward motion, there was a very jerky movement. It was hard to maintain a preselected rate of movement. A lot of stick activity was required both in pitch and roll. Coming to a stop at the corner - here again, a lot of control movement, a lot of vehicle oscillations. Going sideways it was a little easier to maintain a preselected rate than forward, but still it took a lot of movement in pitch and roll. Attitude changes were not excessive. It stayed within the ground track fairly well.

Control feel - too sensitive. Forces were satisfactory, deflections very small. Response was too fast in pitch and roll, but directionally it was okay. The sensitivity was too high. Turns-over-the-spot - there was a tendency to overcontrol attitude because of the fast response in pitch and roll. No difficulty was experienced on turn rates or headings. Crosswind turns - time was satisfactory; it didn't overshoot or undershoot.

There was no problem maintaining heading and coming to a precision hover. Here again, there was too much stick activity. Vertical landing would be doubtful. Quick stops - no problem on forward stop or going sideways. Here again, control motions were excessive. Directional and height dynamics did not affect evaluation.

Overall Evaluation

Objectionable features - too sensitive, with lack of stability especially laterally. It fell off so rapidly; it was difficult to look at the pitch stability. However, it did seem satisfactory. Damping was satisfactory. But it was a very undesirable airplane to fly. No favorable features. Responses were very objectionable in this particular vehicle.

CASE 358 (Continued)

PILOT E PR = A5-1/2

Response characteristics were good but the major deficiency was its oversensitivity in both pitch and roll. Because of the oversensitivity in pitch, I could feel a high-frequency bobble in the machine. But in roll, even though the sensitivity seemed about the same, I didn't feel the bobble. Perhaps this was due to the fact that I put in inadvertent inputs in pitch and not in roll. I do not know.

The air-taxi-around-the-square - no problem. With concentration, I could stabilize it at any rate of movement that I wished. I could hover reasonably precisely at the corners, but I was concentrating because of the excessive sensitivity. The attitude changes required didn't seem to be a problem. It could certainly fly within the ground-track limits with no problem. The response to control inputs - everything was oversensitive but the response was quite reasonable. It was a nice, well-damped attitude system. Turn-over-the-spot - no particular comment. The 90-degree cross-wind turns - had to use a lot of rudder to get around the corner. Certainly the control power was more than adequate.

Precision hover - could accomplish this very precisely except that with the sensitivities as they were, I was consistently bobbling the machine, particularly in pitch through small amplitudes. The quick stops were no problem.

Ovr.all Evaluation

The objectionable features were an oversensitivity in pitch and roll requiring an undue amount of compensation on the part of the pilot.

PILOT F PR = A5

This particular control system demanded considerable pilot attention to make the vehicle behave as the pilot desired. It was a fixed control sensitivity system and it seemed to require a lot of very small control stick movements to keep the attitude centered around the desired attitude. It seemed to me that once I found the right control stick position, I had to keep bucking the stick in various directions just to cancel out little random movements that were initiated by the turbulence.

The air-taxi-around-the-square - it was easy to initiate motion in the desirable direction, although it was very difficult to stabilize and hold a preselected rate of movement. So that aspect of the system was very poor. I could stop fairly precisely although it took considerable pilot attention in order to make the vehicle stop and to hold that attitude which would keep the vehicle over the spot on the ground.

Attitude changes were not excessive in terms of pitch and roll; in fact, they were quite minor. The response of the vehicle to any given input was very rapid. With considerable attention, and as long as I took this course fairly slow and easy, I could remain within the ground-track limits reasonably well. Control deflection, forces, and trim gave the impression of trying to balance on top of a ball. I always had to put in small corrections in order to keep from starting to roll off the ball in one direction or another.

Response to control inputs - the control stick response was very quick. Ability to hold heading was not a problem in this machine. Again, with considerable pilot attention, I could remain over a given spot in a hover during a turn as long as I anticipated the wind effects. However, it took many, many small corrections in pitch and roll in order to keep attitude constant. It required a lot of pilot attention.

Ability to hold preselected heading turn rate was good with this particular machine. I could stop quite reasonably on a preselected heading. I could initiate the 90-degree crosswind turns. The vehicle was very maneuverable; in fact, it was maneuverable to an excess. It gave that impression. However, it didn't really happen. I was able to basically turn into the wind and stop on the desired heading without any undershoot and overshoot tendencies. The control activity was, as I stated earlier, many, many small inputs in order to control the attitude.

Once established in a hover with this control piloting technique of many, many small corrections on the control stick, I could maintain a reasonably precise hover and position. However, it did take considerable pilot attention to attitude and corresponding stick inputs in order to maintain the attitude desired. Therefore, the control activity, though not large in excursions, was very high in frequency.

Quick stops worked out fairly well with this kind of control system. I was able to accelerate to a reasonably high airspeed at my discretion, and the aircraft responded very quickly to intended attitude changes through the control stick in order to initiate the quick stop. In the heading and altitude, with proper coordination on the collective stick, altitude remained fairly constant and the heading remained constant also. The directional and height dynamics were the same as before - quite reasonable.

Overall Evaluation

Objectionable feature was the excessive pilot attention demanded to monitor the aircraft attitude in the many, many and very high-frequency stick inputs in order to maintain a desired attitude. The objectionable features certainly outweighed the favorable features, but the maneuverability of this aircraft could be considered reasonably favorable.

Special piloting techniques were required to an extent that one must hold the control stick very close to neutral and put in many, many small inputs. The total stick displacement from the center position was very small, even in quite extreme maneuvers, so I feel this kind of control system would require some practice and special piloting technique.

CASE 358 (RERUN)

X_u	$= Y_v$	$= -0.05$	$M_\delta = L_\delta$	$= 1.350$
$M_u g$	$= -L_v g$	$= 0.33$	λ	$= 0.374$
M_q	$= L_p$	$= -1.785$	ω_n	$= 1.044$
M_θ	$= L_\phi$	$= -1.547$	ζ	$= 0.700$

PILOT D   PR = A4-1/2

The vehicle seemed to fall off in pitch and roll but it appeared fairly stable. Response was okay and dynamics were barely damped.

In the air-taxi-around-the-square, there was no particular difficulty initiating motion in either direction. The vehicle stayed fairly well on a selected rate. There was quite a bit of stick activity flying this particular mission, and coming to a hover at the corners and so forth. Attitude changes were not excessive in pitch and roll. It stayed fairly well within the ground track. Control deflections and so forth were satisfactory. Response was okay in all axes; sensitivity seemed satisfactory.

Turns-over-the-spot - here again, quite a bit of stick activity was required. I was able to stay fairly close to the selected position. Turn rate and so forth were satisfactory. Crosswind turns - I overshot on the first, probably going a little too fast. I was able to get quite a bit of speed going across the square with this configuration.

Hovers worked out pretty well; I was able to trim it quite well. I think it would have been adequate for a vertical landing. Quick stops worked out okay. I don't believe that attitude changes were excessive. Secondary dynamics did not affect the evaluation.

Overall Evaluation

The objectionable feature was the lack of stability, but it wasn't too bad to fly. Favorable features - nothing outstanding.

CASE 359

$X_u = Y_v$	$= -0.05$	$M_\delta = L_\delta$	$= 4.050$
$M_u g = -L_v g$	$= 0.33$	λ	$= 0.374$
$M_q = L_p$	$= -1.785$	ω_n	$= 1.044$
$M_\theta = L_\phi$	$= -1.547$	ζ	$= 0.700$

PILOT D PR = U8

This configuration was fairly unstable both in pitch and roll. It rolled off and pitched down rather rapidly. Response was extremely fast. Sensitivity was extremely high.

Air-taxi-around-the-square - when initiating motion, there was a lot of pitch and roll oscillation. To maintain a preselected rate of movement, constant stick or attitude change was required. Hovers at the corners weren't very precise because of the constant oscillations of the vehicle. Pitch and roll attitude changes were not excessive. It stayed within the ground track fairly well. Control feel was overly sensitive, forces very light, and deflections very minor. Response was very, very fast.

Turns-over-the-spot - here again, the same comments apply on attitude control. It made me very cautious of performing these maneuvers, in order not to overcontrol or lose the vehicle. Turn rates and so forth were good. Crosswind turns - time was not excessive. It did not undershoot or overshoot. Precision hovers weren't very precise. The constant, rapid oscillations of the vehicle actually fed inputs to the stick because of the difficulty of holding the stick still. Vertical landing would have been very questionable.

Quick stops - same comments on the oscillations in pitch and roll. Attitude changes weren't excessive. Control motions were very minor. Again, there were a lot of oscillations. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features were the constant oscillations in pitch and roll, the lack of stability, oversensitivity, and the extremely fast response. There were no favorable features. It was controllable but with much difficulty.

PILOT E PR = U8

The first problem was general oversensitivity, plus very large disturbances in pitch attitude. The roll control sensitivity seemed to be the worst offender, but the pitch was such that I couldn't stop making inadvertent inputs. The pitch did not seem as much of a problem as the roll, in terms of really overcontrolling. But in roll I didn't have the problem of inadvertent small disturbances that I couldn't stop from

putting in. However, both pitch and roll were much too sensitive. The oversensitivity masked everything else.

The taxi-around-the-square was a very careful maneuver and I couldn't really judge too much about it. I certainly was not doing it in the same manner as I would normally perform the task. The response in pitch and roll was quite acceptable, but the sensitivities were much too high, particularly in roll. I felt that if I didn't pay attention, I could really get in trouble.

Turning-over-the-spot - could get around all right. Attiude control with regard to trimming the wind out wasn't a problem, but there was a constant disturbance in pitch attitude. Ninety-degree crosswind turns - couldn't really do the maneuver in a normal fashion because of the sensitivity. No further comments. Precision hover - could remain over the spot reasonably well in spite of the sensitivities.

The biggest problem was the disturbance in pitch attitude. Quick stops couldn't really be performed in the normal fashion because of the sensitivities. Lateral quick stops - it was evident that if I put in the control inputs fairly rapidly to arrest the motion, I would quickly hit the simulator stops. I think one could get into real trouble.

Overall Evaluation

In summary, it was controllable but certainly unacceptable.

PILOT F PR = U9

This was one of those supersensitive control systems which demanded complete and total pilot attention in order to safely control the vehicle attitude. Any lax attention on the part of the pilot or head-in-the-cockpit activity easily could have resulted in control of the aircraft being lost from extremely fast reaction of the vehicle and unintended control input. Any tendency of the pilot to overcontrol would result in more than likely structural damage to the aircraft, or complete loss of control of the aircraft.

Control sensitivity was fixed. It was almost impossible to hold a preselected rate and stabilize on a preselected rate of movement. I could stop relatively precisely in a hover, but it was a very jerky, unsteady type of maneuver. Excessive attitude changes were not required. It was a full-time job just to keep the attitude close to level. At anything other than just slightly away from level, the vehicle started generating movements at a rapid rate in whatever direction it was tilted.

Ability to remain within the ground-track limit was not too bad, though certainly below average, but with good concentration I could come fairly close. I did deviate considerably from the track limits, but the system could be maneuvered with a little bit of luck and skill. Control feel, forces, deflection, and trim... the feel was so sensitive that I was not even conscious of it as a control feel and force.

I was really concerned about extremely small deflections around the trim point. Response to control inputs in the pitch and roll axes was supersensitive as noted earlier. Ability to hold heading - of course, that was a different sensitivity and it

was good. Turns-over-the-spot and ability to remain over the spot were marginal. I shouldn't say marginal. I could stay in the area, but to hold a real precise spot was very difficult.

Attitude control in pitch and roll was constantly deviating from the desired pitch and roll attitude and required constant pilot attention. Ability to initiate rates and turns, stabilize turn rates, and stop on a preselected heading, was not too bad. In the 90-degree turns into the wind, time to accomplish the maneuver was normal. It did have some overshoot or undershoot tendencies due to overcontrolling on the control stick during the maneuver. Ability to establish a heading and a position over the spot in rough terms was not too bad. Real precise maneuvers were marginal and hardly acceptable.

Control activity was extremely high, but had a very high feel of control power. The deflections, of course, did not need to be very large at all. I would no sooner put a control input in when I realized I had to take it out, so I was constantly putting in small corrections. Ability to establish and maintain precise hover was very poor. It required complete pilot attention with frequent control activities to maintain attitude position. Control for a vertical landing was minimally acceptable.

Quick stops could be accomplished quickly in normal time. Excessive attitude changes were not required. Ability to hold heading and altitude was reasonable - not real good, but in the ball park and not too bad. Control motions again consisted of constant small inputs. No large amplitude inputs were required. Secondary dynamics didn't enter into this evaluation.

Overall Evaluation

Objectionable features were the supersensitivity of the vehicle to control inputs, the quickness of response, the requirement of the pilot to concentrate on maintaining attitude, and the need to keep from overcontrolling the vehicle. I don't believe there were any favorable features. Special piloting techniques required were the extreme concentration and attention to prevent overcontrolling the vehicle, which if allowed to occur would result in structural damage and possible loss of the aircraft.

CASE 360

$X_u = Y_v$	$= -0.05$		$M_\delta = L_\delta$	$= 6.075$
$M_u g = -L_v g$	$= 0.33$		λ	$= 0.374$
$M_q = L_p$	$= -1.785$		ω_n	$= 1.044$
$M_\theta = L_\phi$	$= -1.547$		ζ	$= 0.700$

PILOT D PR = U8

This particular configuration was extremely sensitive in pitch and roll. Response was very fast. Frequency was such that PIO's were introduced during the mission in both pitch and roll.

Air-taxi-around-the-square - initiating motion caused a lot of oscillation in the vehicle, both in pitch and roll. It was difficult to hold a preselected rate of movement. Precise hovers at the corners and coming to a stop involved a lot of control motion. Sideways movement when making lateral inputs, tended to induce a PIO. Pitch and roll attitude changes weren't excessive. Ground track was maintained fairly well.

Control deflections were very small. Response was much too fast in both pitch and roll axes, and sensitivity was too high. Turns-over-the-spot worked out fairly well. Pitch and roll attitude changes were not excessive. Again, though, there were a lot of oscillations in pitch and roll. If the stick were let go, the oscillations of the vehicle would cause the control stick to oscillate back and forth, and the vehicle would diverge.

Crosswind turns - maneuver time was satisfactory. It didn't overshoot or undershoot. There was a lot of control activity and a lot of pitch and roll oscillations. Precision hover wasn't really very precise because of the vehicle movement. I was unable to stop all the oscillations. Vertical landing would have been pretty scary.

Quick stops worked out fairly well. On the quick stop sideways with the wind, the vehicle did get into a lateral PIO. Secondary dynamics did not affect the evaluation.

Overall Evaluation

Objectionable features - response was too fast and too sensitive, and there was a lack of stability. There were no favorable features. It was controllable, but with difficulty.

PILOT E PR = U8-1/2

This configuration was very much oversensitive in both pitch and roll. The basic response characteristics, as far as I could tell, would have been all right except for the fantastic control sensitivities. It seemed to be more difficult to control in roll actually. It frequently went stop to stop on the simulator with just a little bit of inattention in roll.

Air-taxi-around-the-square - oversensitive. I could do the job with an extreme amount of attention. Turns-over-spots - it was very hard to be precise and all the concentration had to go into not overcontrolling. It could get around over the spot. Back to the air-taxi maneuver, it was very difficult because I couldn't put in attitude changes very rapidly without wildly overcontrolling. It was very difficult then to arrest any motions once they started. It tended to slide far beyond the point at which I wanted to stop.

Ninety-degree crosswind turns were accomplished in a sort of series of steps, and so it took a long time to accomplish the maneuver. It tended to undershoot because of the extreme caution used. Control activity consisted of a lot of inadvertent low-amplitude, high-frequency inputs. It was difficult to be precise in the hover because I couldn't use the controls the way I wanted. All concentration had to go to not over-controlling. There wasn't much left over to do what I wanted to do with the machine. I think it was marginal in terms of landing.

Quick stops - I couldn't really do a proper quick stop because of the caution required to prevent overcontrolling. Control motions were small and very numerous.

Overall Evaluation

Objectionable features - mainly the oversensitivities. It was hard to judge whether I would lose control or not. For instance, in roll, with a little inattention and abrupt maneuvering, I could easily hit the simulator stops so it was hard to know whether I would really get into serious difficulties if the stops weren't there. The basic characteristics, aside from the oversensitivity, were good enough that they helped to compensate slightly for the oversensitivity.

PILOT F PR = U9

This was a hypersensitive, super fast-reacting control system which was very undesirable, with very definite PIO tendencies in pitch and to a lesser degree in the lateral axis. Control sensitivity was fixed.

In the air-taxi-around-the-square, the ability to initiate motion was poor. I could get the machine in the right direction, but stabilizing some preselected rate of movement was nearly impossible. It was either too fast or too slow. I was always just putting in corrections trying to modify whatever the machine was doing.

Ability to stop precisely and come to a hover at the corners was very poor due to the inability to control the rates of movement of the machine, and when I tried to stop a rate of movement I often times came to a PIO tendency. I would have to concentrate then on holding the stick still and letting the thing stabilize a little bit and correct from that point.

Excessive attitude changes were certainly not required due to the extreme quick reaction of the aircraft to extremely small inputs to the control stick. Ability to remain within the ground-track limits was certainly below average and poor.

CASE 360 (Continued)

Control feel, forces, deflections - the whole system was wormy and it was difficult to break it down into which area was worst. It was a very jerky ride throughout due to the quick response of the aircraft and it caused the pilot to feed unintended inputs back into the stick, inducing PIO. So there was very little feel to the stick. I was concentrating on trying to hold it around neutral and trying to put the smallest amount of pressure into the stick in order to make the aircraft react as the pilot wanted. However, I could not do this to my satisfaction because of the rough ride of the vehicle.

Response to control inputs was too fast, too quick, too much. Ability to hold heading, of course, was reasonable. In the turns-over-the-spot the aircraft was not affected by the wind very much as far as the pilot was concerned; he was so concerned with maintaining attitude and basic control of the aircraft that wind effects either were easily overcome or just weren't seen.

Attitude control in pitch and roll was extremely difficult to maintain. Ability to initiate turn rate and stabilize and hold preselected turn rates, was good. However, it was somewhat degraded by the pilot workload on pitch and roll control. Ability to stop on preselected headings was good. In the turns into the wind, the time to accomplish the maneuver was a little bit longer than normal because I couldn't really be sure of attaining a safe rate of movement across the ground, and I was slow in turning the aircraft and maintaining attitude changes for fear of overcontrolling and possibly losing control of the vehicle. The vehicle was reacting far too much so I assume there were inputs to the control system of extremely high frequency but small amplitude.

Control power certainly was adequate and, I would say, extreme. Precision hover - I could reasonably well establish a ball park position in terms of heading and attitude. However, it required complete pilot attention to maintain that attitude. It was a very rough ride in the cockpit, with constant vehicle deviation from what the pilot wanted for attitude position. At best it would be extremely marginal for a vertical landing, with high probability of contacting the ground while the aircraft was pitching or not in the best landing attitude. I think it would be very likely that damage and extremely poor landings would result from this control system. Control activity was extreme and inputs frequent and of small amplitude.

Quick stops - had difficulty moving at what I considered a comfortable rate across the ground. Then, as I was trying to slow down the vehicle, I encountered a very definite PIO trend. In trying to bring the nose of the aircraft up to show my rate of movement across the ground, extreme pilot attention was required to dampen out those vehicle movements in order to maintain control of the aircraft. Heading and altitude control were compromised by the concern with pitch control; however, it was not too bad. Basically I don't think the height and directional dynamics affected anything in terms of pitch and roll evaluation.

Overall Evaluation

Objectionable features - supersensitive control system, super fast-reacting, PIO tendencies, very rough cockpit ride. I don't think there were any favorable features. Special piloting techniques were required to prevent entering PIO maneuvers, especially in pitch. Less was required in the lateral axis.

APPENDIX III

PROBABILITY DENSITY AND POWER SPECTRAL DENSITY PLOTS

All of the probability density and power spectral density plots were produced from data for the entire record run, not for an individual maneuver or for a portion of the flight. A guide to these plots is given in Table IX. The data were speed scaled by a factor of 128:1. This was done to raise the frequency spectrum up to the capability of the analog equipment used to process the data.

The power spectral density plots were processed with a Technical Products TP-625 Wave Analyzer in conjunction with TP-633 Multiplier. This system has a frequency response of 6 Hz to 25 k Hz. By use of the speed scaling technique the frequency spectrum is increased 128:1 (i.e., 1 Hz becomes 128 Hz). A functional block diagram for the power spectral density analyzer is given in Figure 58. In words, the power spectral density function is estimated by the following operations.

1. Frequency filtering of the signal by a narrow band-pass filter.
2. Squaring of the instantaneous value of the filtered signal.
3. Averaging the squared instantaneous value over the sampling time.
4. Division of the mean square output by the band width.

As the center frequency of the narrow band-pass filter is moved, a plot of the power spectral density function versus frequency is obtained.

The probability density data were also speed scaled 128:1 because the same tape loops were used that were used for the power spectral density analyses. The probability density plots were processed with a Bruel and Kjaer Model 161 Probability Density Analyzer. This system has a frequency response of D.C. to 20 k Hz. A functional block diagram for the probability density analyzer is given in Figure 59. In words, the probability density function is estimated by the following operations.

1. Amplitude filtering of the signal by a narrow amplitude window.
2. Measurement of the total time spent by the signal within the window.
3. Averaging of the time spent within the window over the sampling time to obtain the average portion of time spent by the signal within the window.
4. Division of the average portion of the time spent within the window by the window width.

As the center voltage of the window is moved, a plot of the probability density function versus voltage level is obtained.

The rms value of the data was read from a Ballantine Model 321 True RMS Voltmeter and the analyzer was normalized to this value.

An examination of the probability density plots reveals a characteristic in Case 360 not present in the other cases, i.e., Figure 79 has a shape very close to the characteristic shape of the probability density of a pure sine wave. Figure 78 shows this to a lesser extent. The power spectral density plot of Figure 80 indicates a substantial energy peak at 4 Hz. The explanation for this is that this case had a very high preselected control sensitivity. The sensitivity was so high that in the simulator with the pilot's hand on the stick the system was essentially neutrally stable. The pilot comments for this case are dominated by concern for not overcontrolling.

It should be noted that the areas under the probability density curves do not equal values of unity exactly. This problem has been investigated and appears to be related to the approximate nature of the analog equipment and techniques used in analyzing the data. For the purpose of obtaining cumulative probability data the area of each of the probability density distributions is given on the plots. Cumulative data obtained from a plot could be divided by this value in order that the total cumulative probability would be unity. However, the shape of the cumulative probability curve would still be subject to a degree of approximation. And this approximation is represented by the area value listed on the plots.

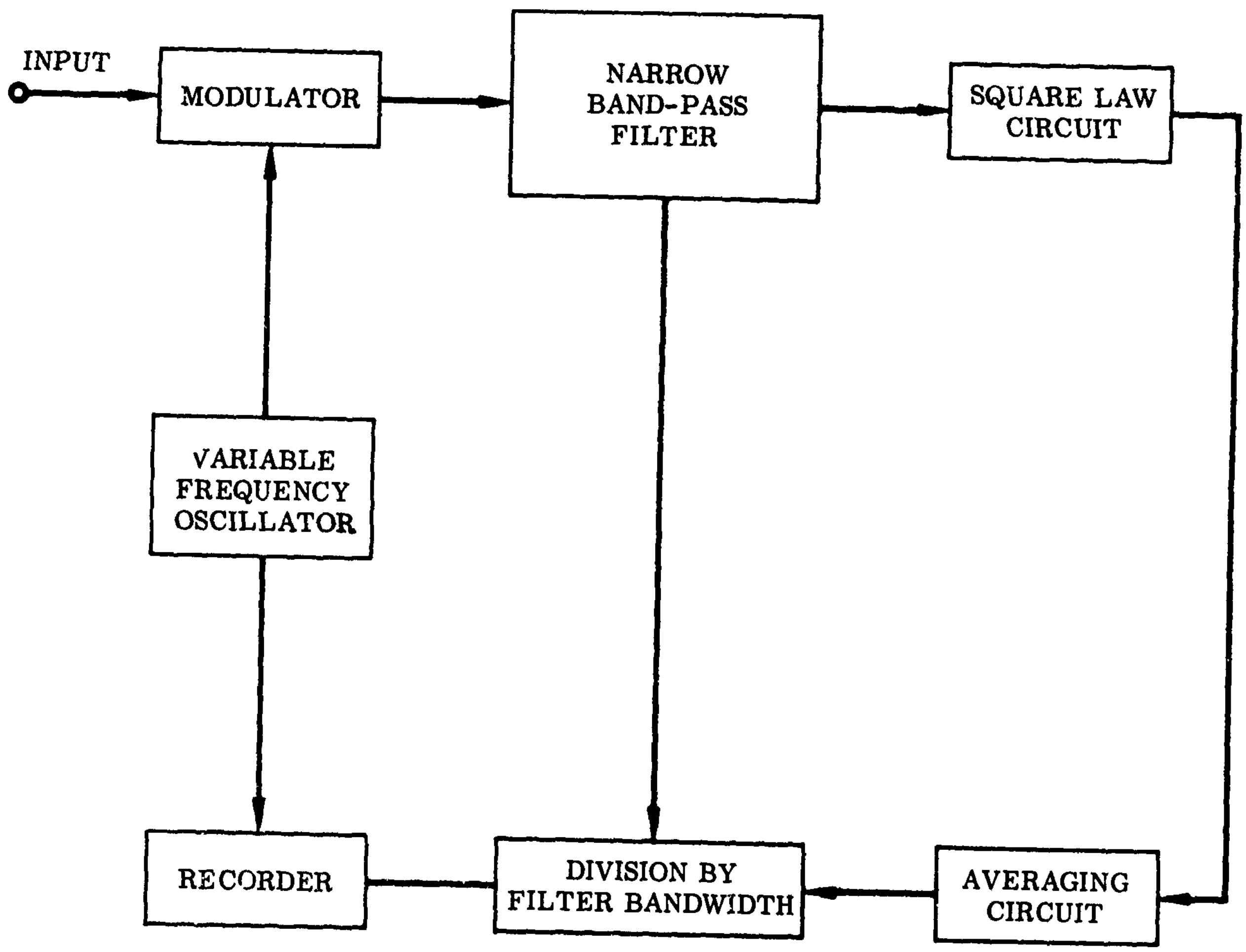

FIGURE 58. FUNCTIONAL BLOCK DIAGRAM FOR POWER SPECTRAL DENSITY ANALYZER

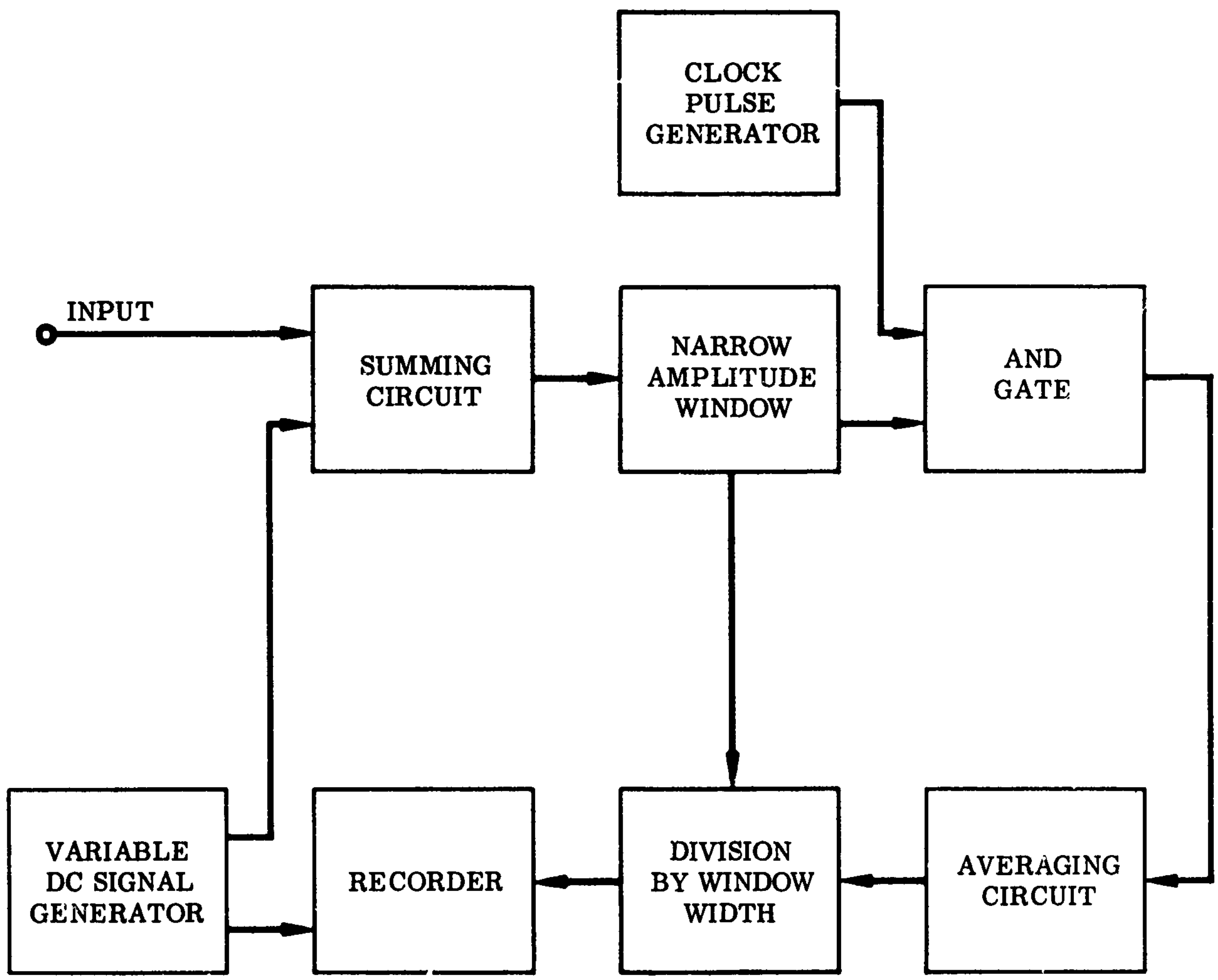

FIGURE 59. FUNCTIONAL BLOCK DIAGRAM FOR PROBABILITY DENSITY ANALYZER

TABLE IX. GUIDE TO PROBABILITY DENSITY AND POWER SPECTRAL DENSITY PLOTS

CASE	PILOT	$M_u g$	X_u	ω_n	ζ	M_δ	FIGURE NOS.		
							$P(\delta_e)$	$P(M_c)$	$\Phi(\delta_e)$
120	B	0.33	-0.20	1.91	0.52	0.819	60	61	62
120	C	0.33	-0.20	1.91	0.52	0.446	63	64	65
139	B	1.00	-0.20	1.84	0.11	0.653	66	67	68
139	C	1.00	-0.20	1.84	0.11	0.471	69	70	71
356	E	0.33	-0.05	1.044	0.70	0.300	72	73	74
314	E	0.33	-0.05	1.044	0.70	0.586	75	76	77
360	E	0.33	-0.05	1.044	0.70	6.075	78	79	80

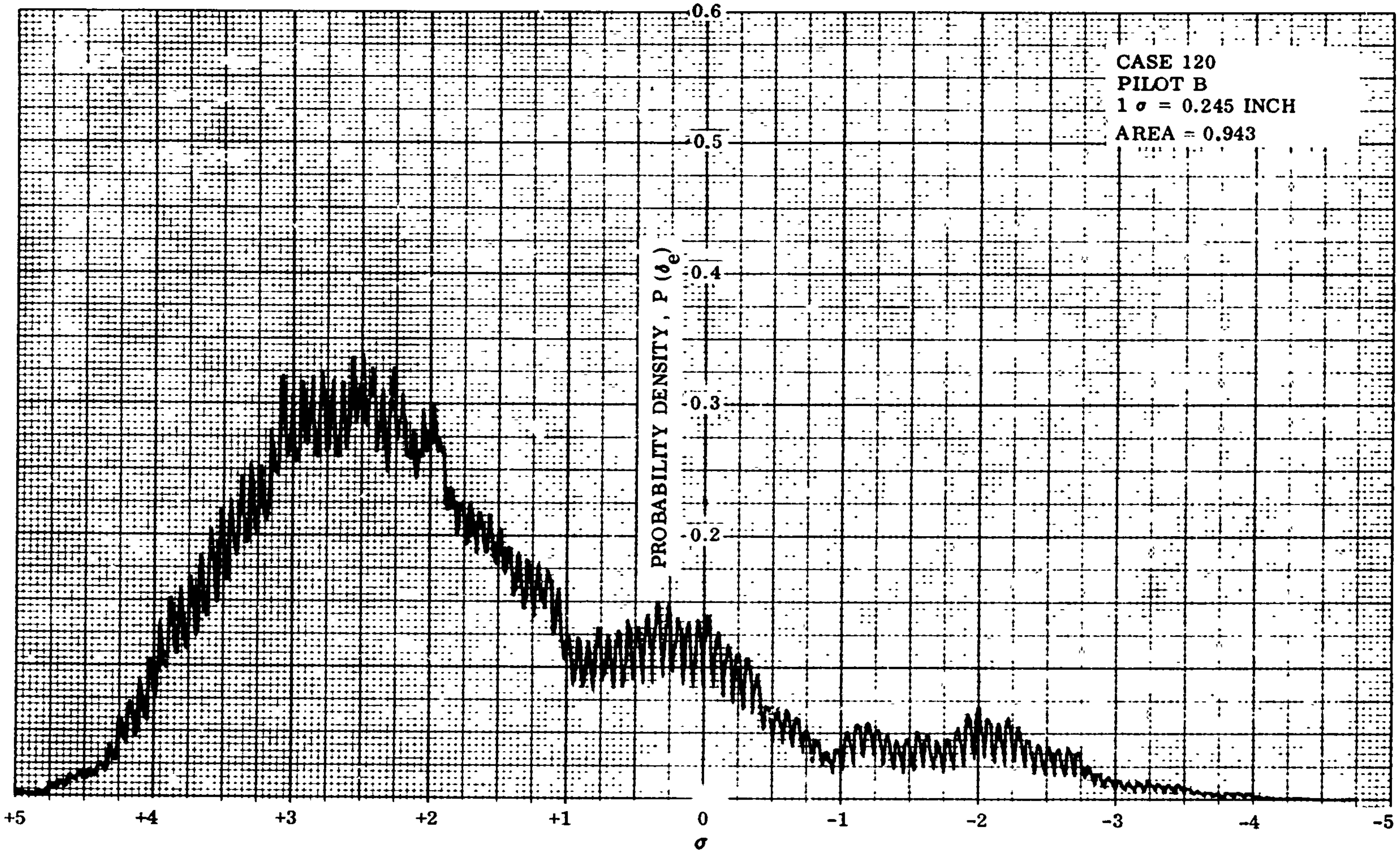

FIGURE 60. STICK POSITION PROBABILITY DENSITY DISTRIBUTION- PITCH CONTROL

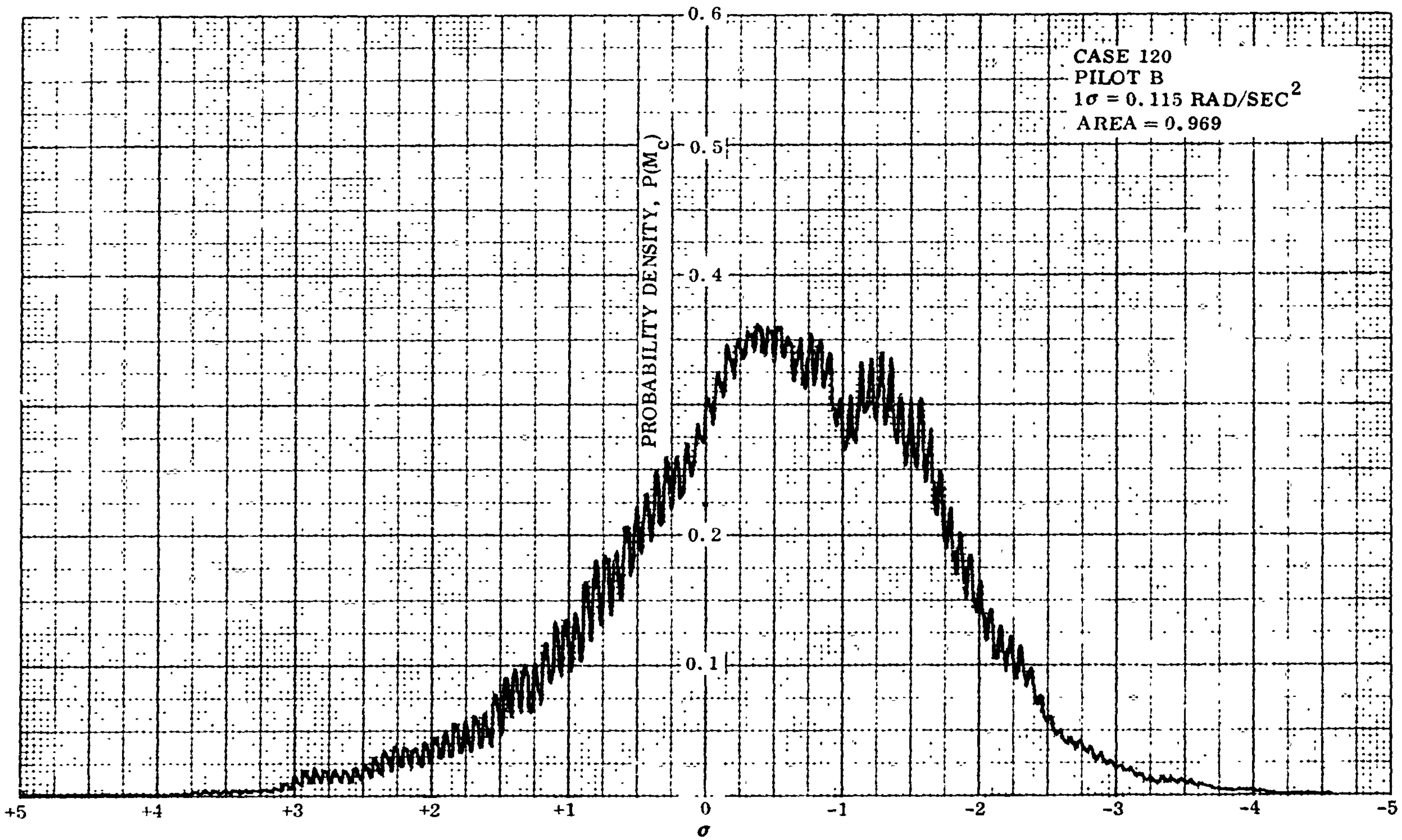

FIGURE 61. INPUT PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

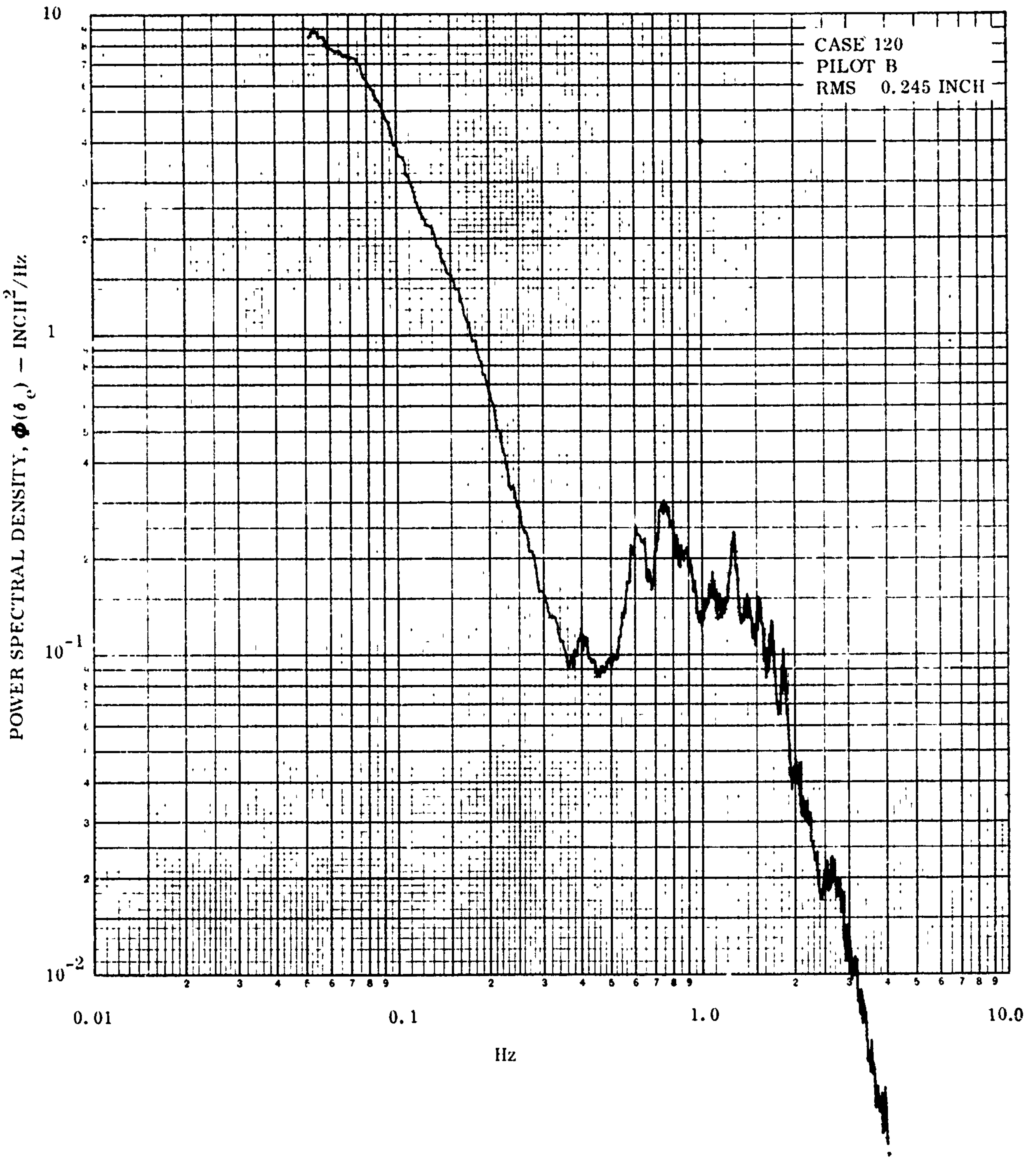

FIGURE 62. STICK POSITION POWER SPECTRAL DENSITY DISTRIBUTION
PITCH CONTROL

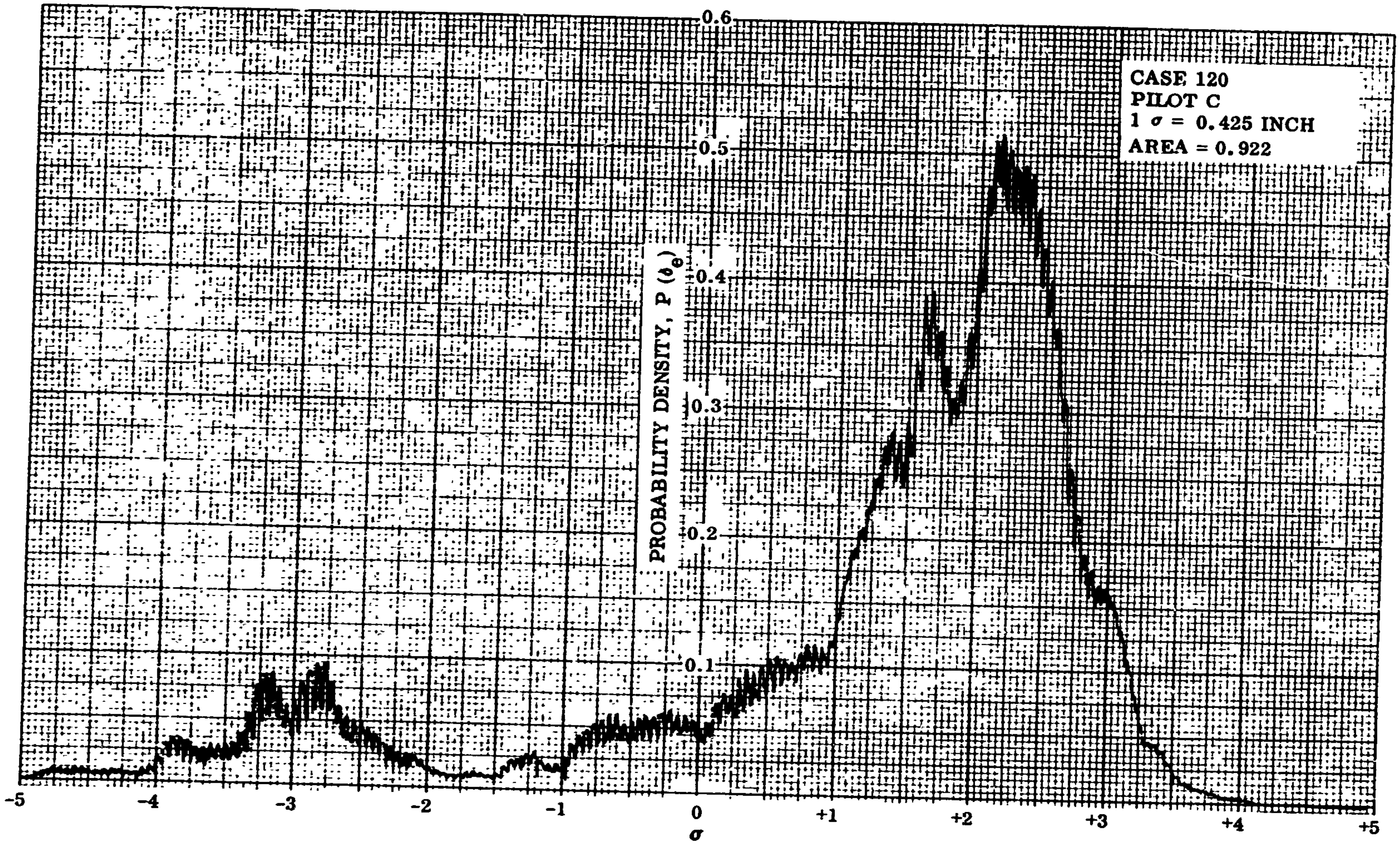

FIGURE 63. STICK POSITION PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

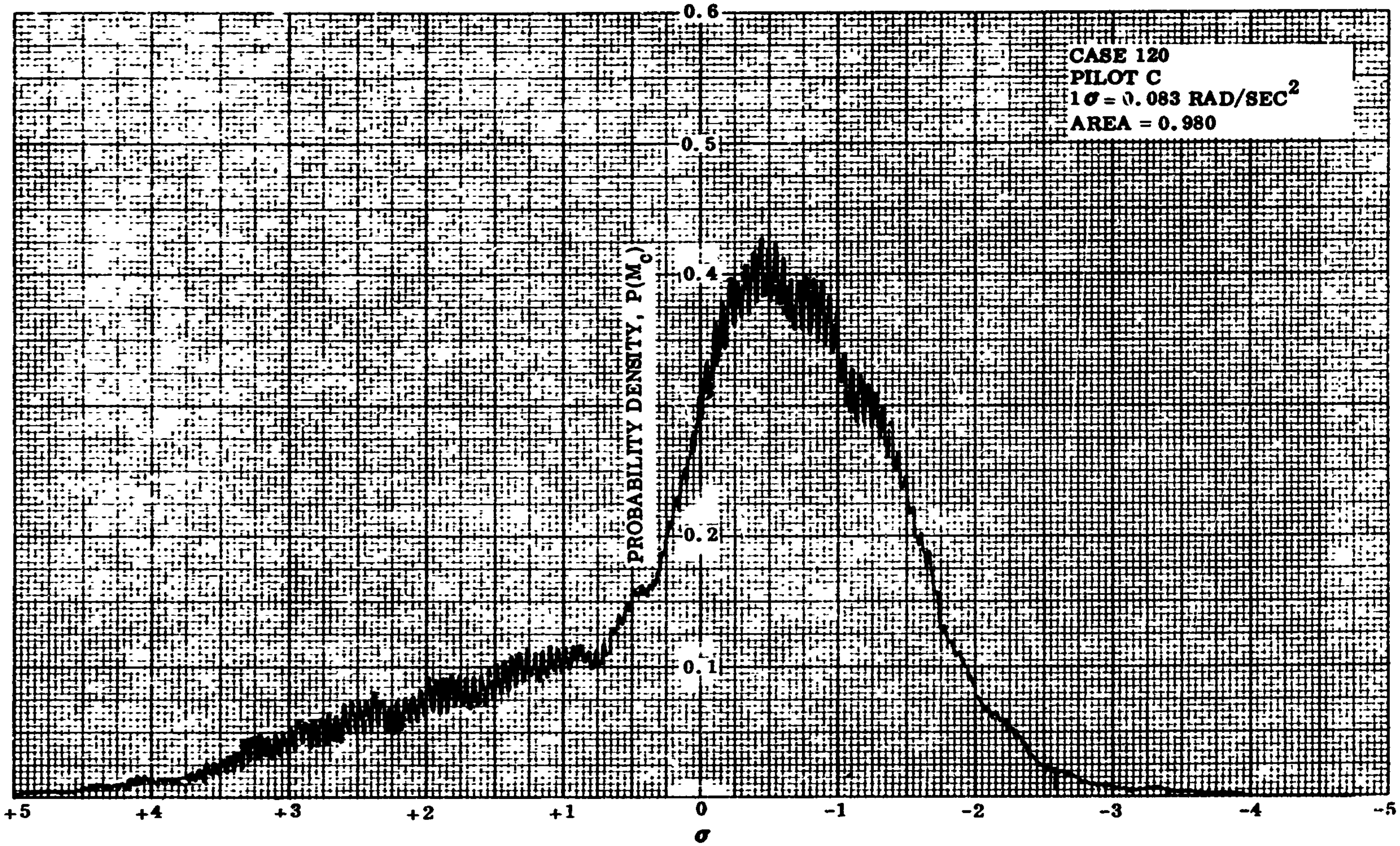

FIGURE 64. INPUT PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

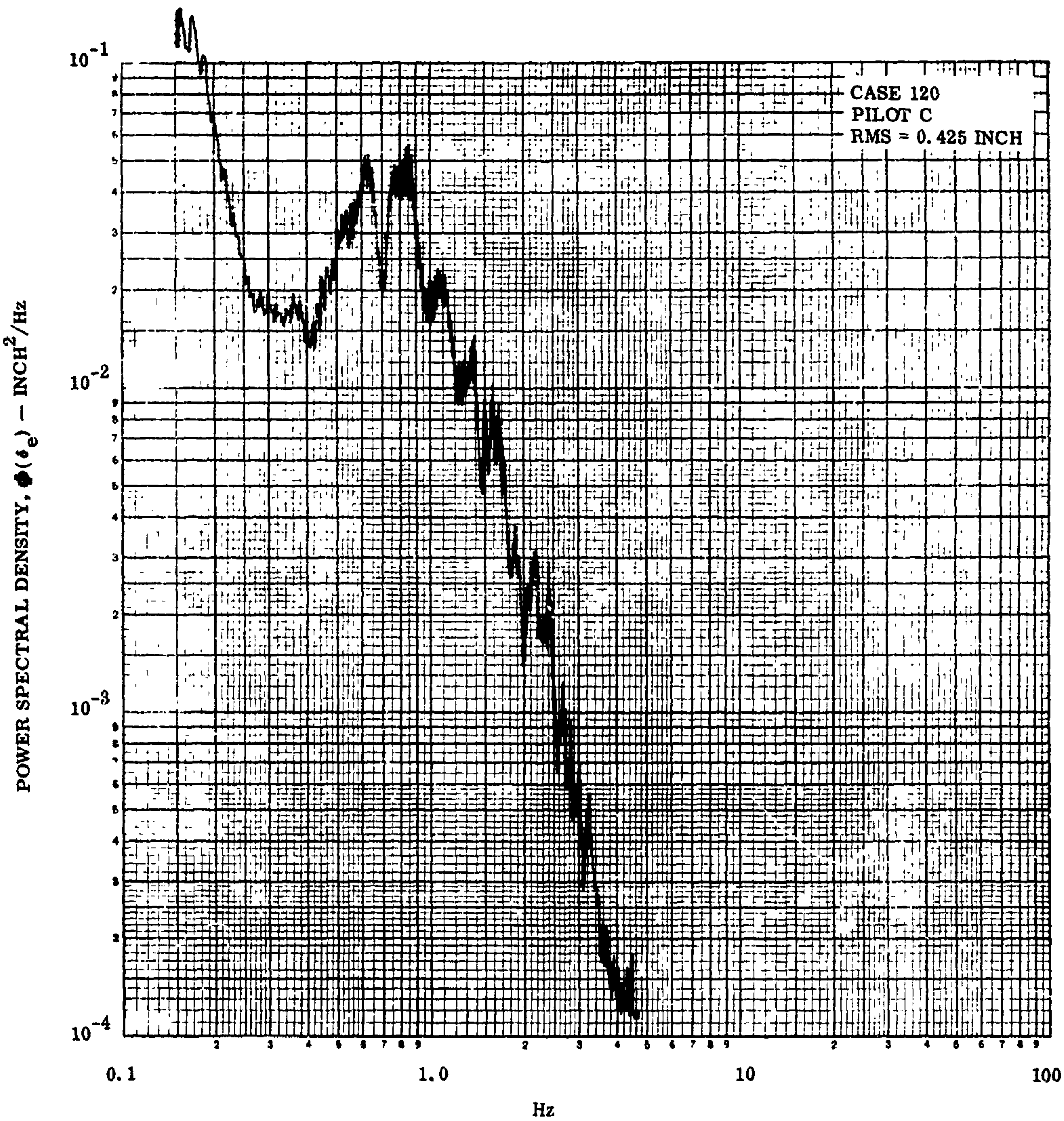

FIGURE 65. STICK POSITION POWER SPECTRAL DENSITY DISTRIBUTION - PITCH CONTROL

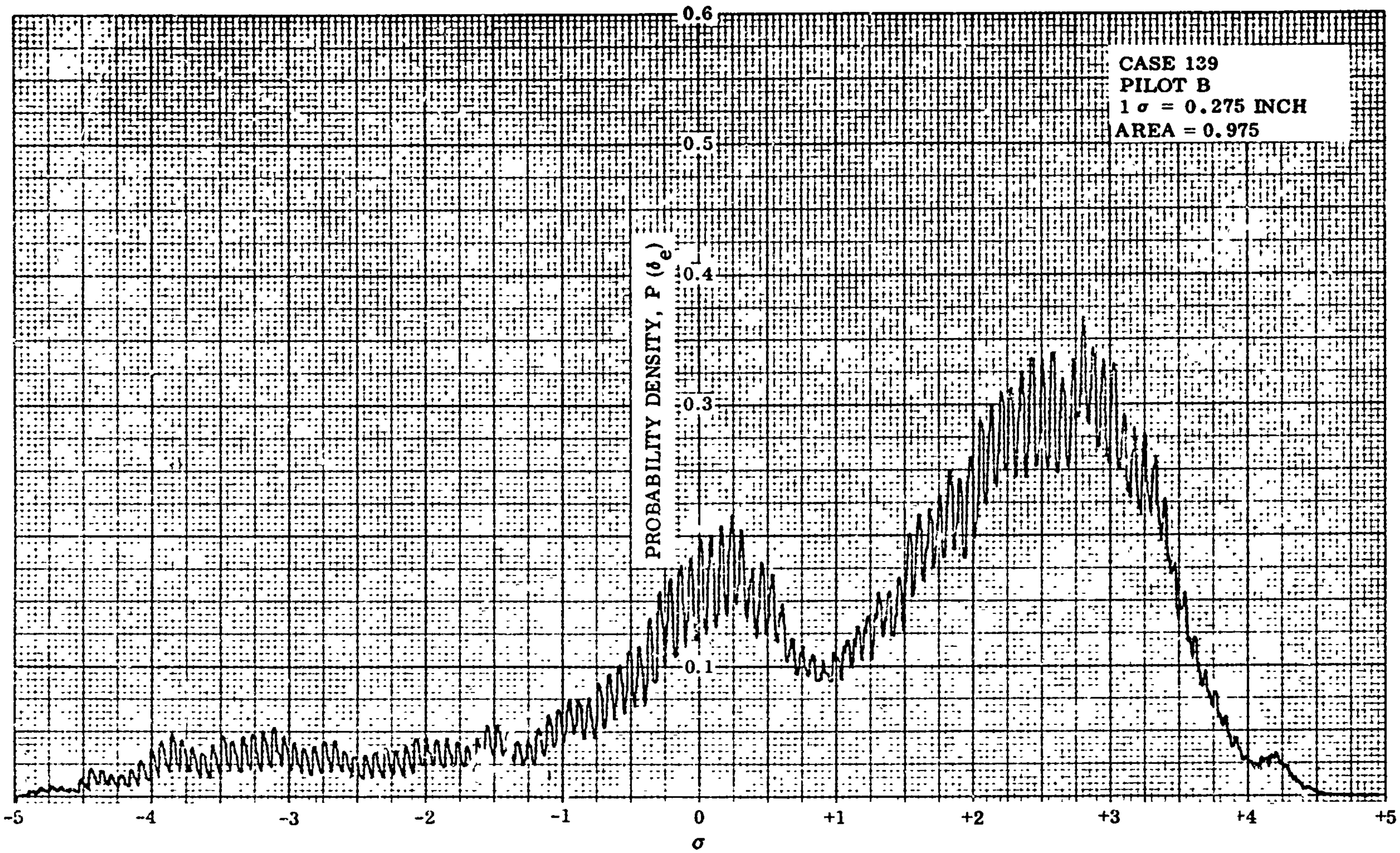

FIGURE 66. STICK POSITION PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

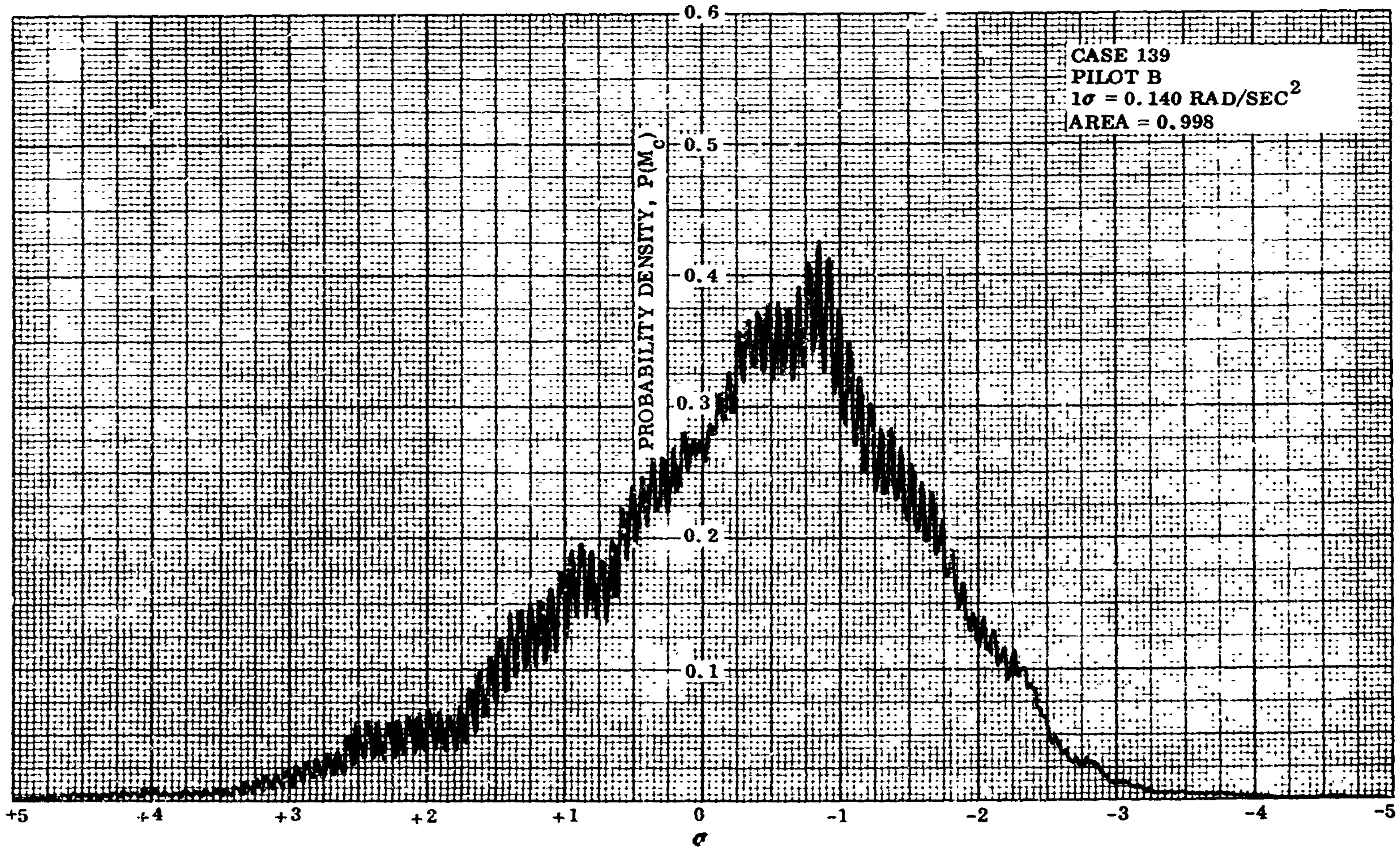

FIGURE 67. INPUT PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

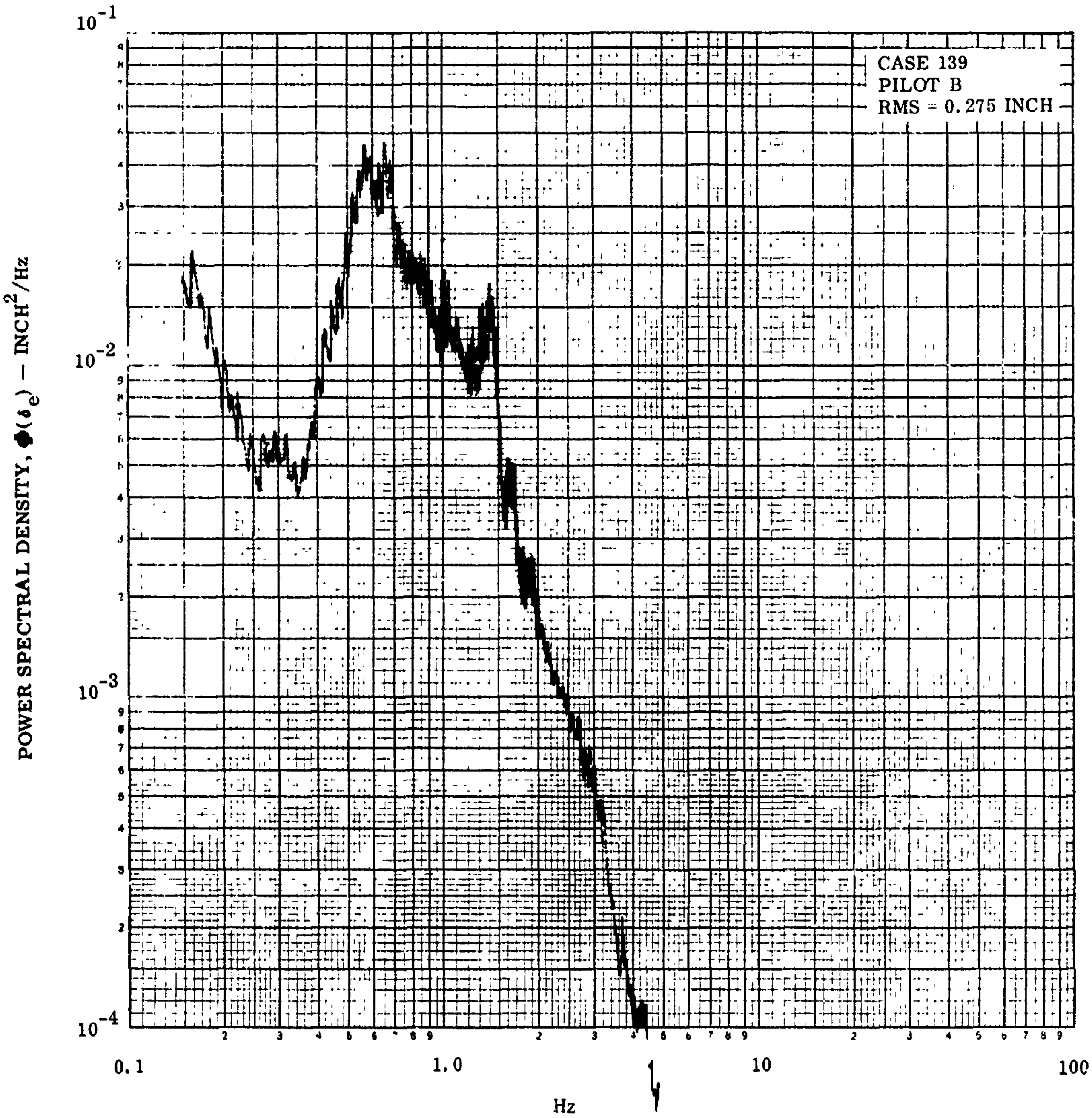

FIGURE 68. STICK POSITION POWER SPECTRAL DENSITY DISTRIBUTION - PITCH CONTROL

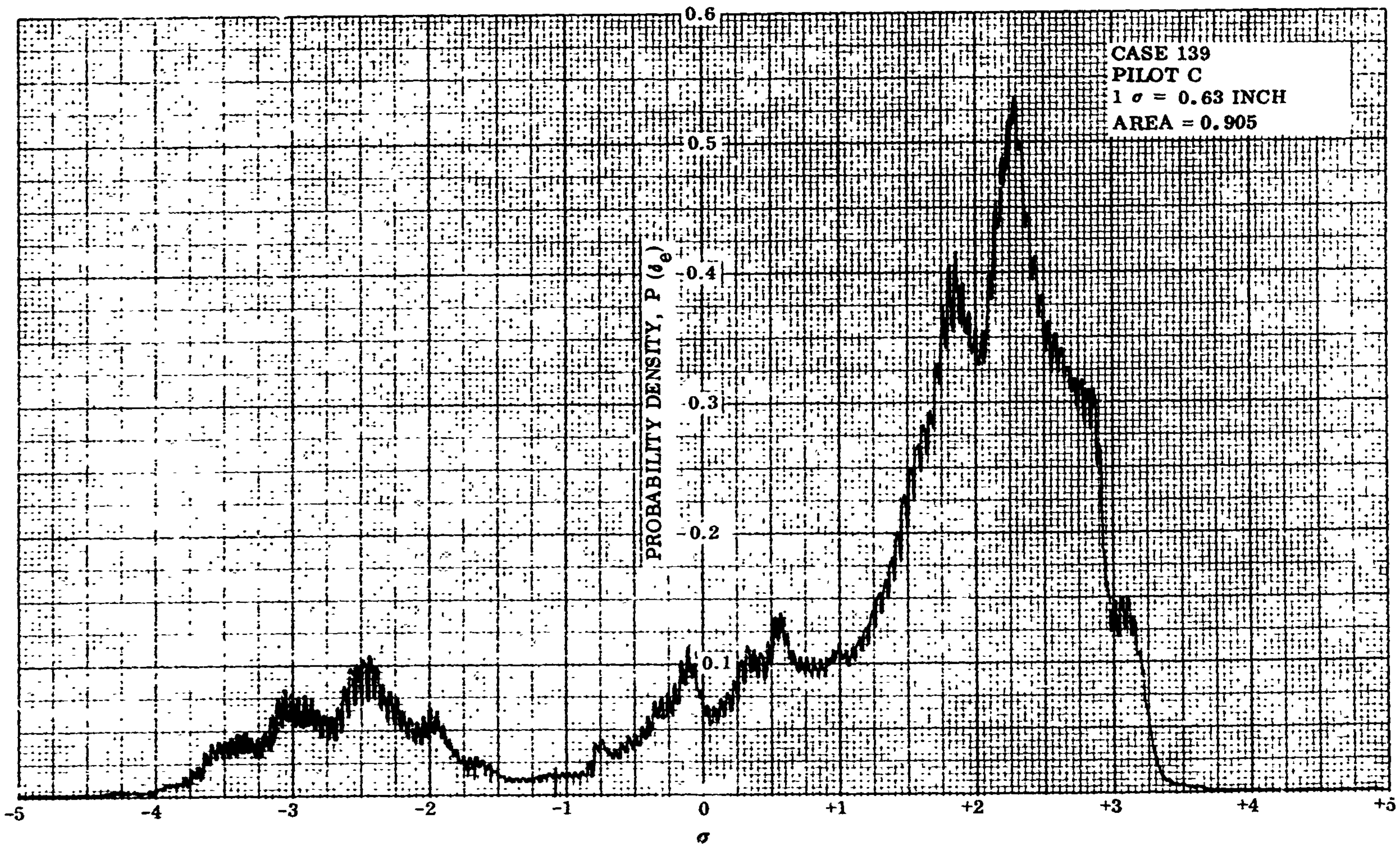

FIGURE 69. STICK POSITION PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

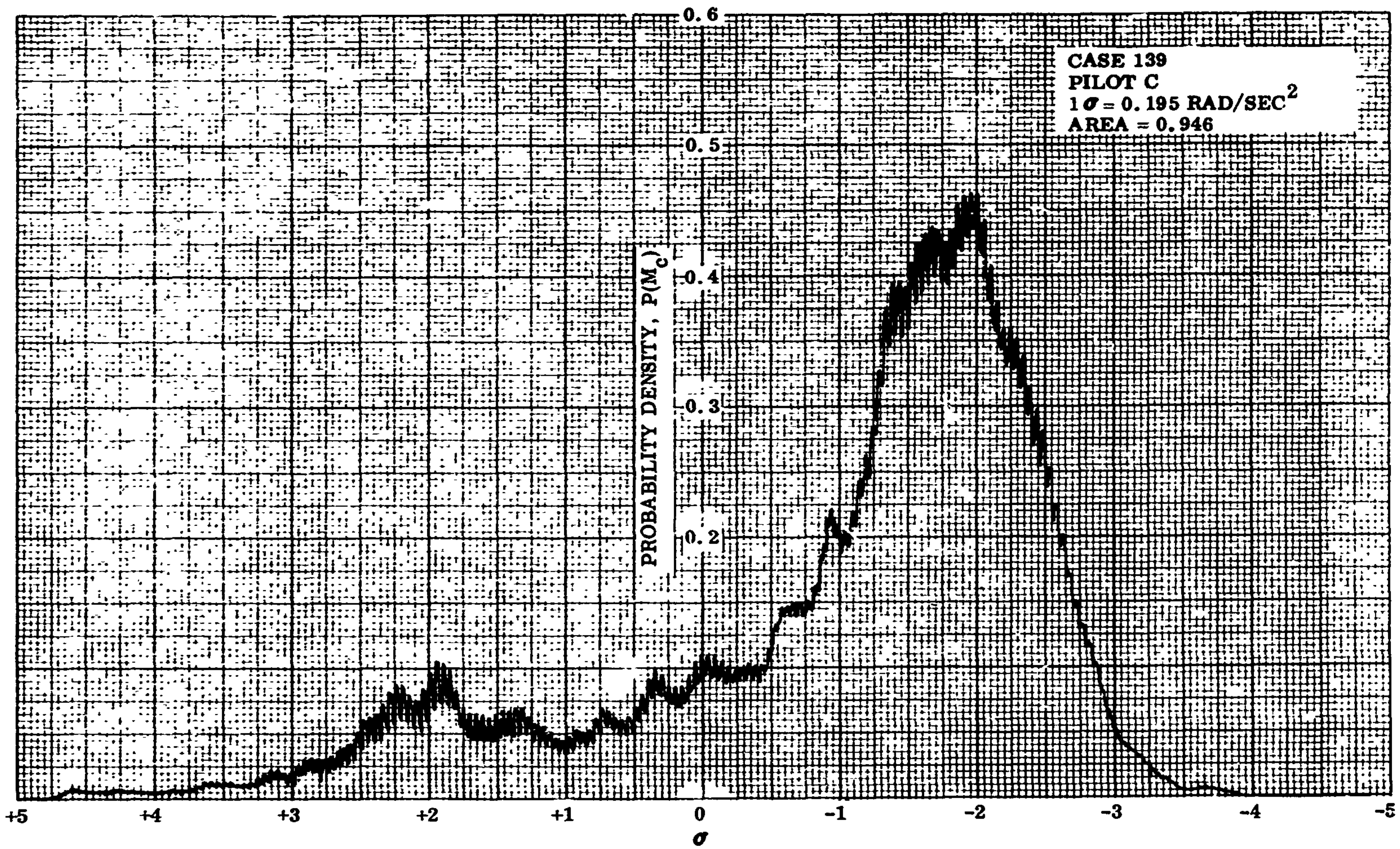

FIGURE 70. INPUT PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

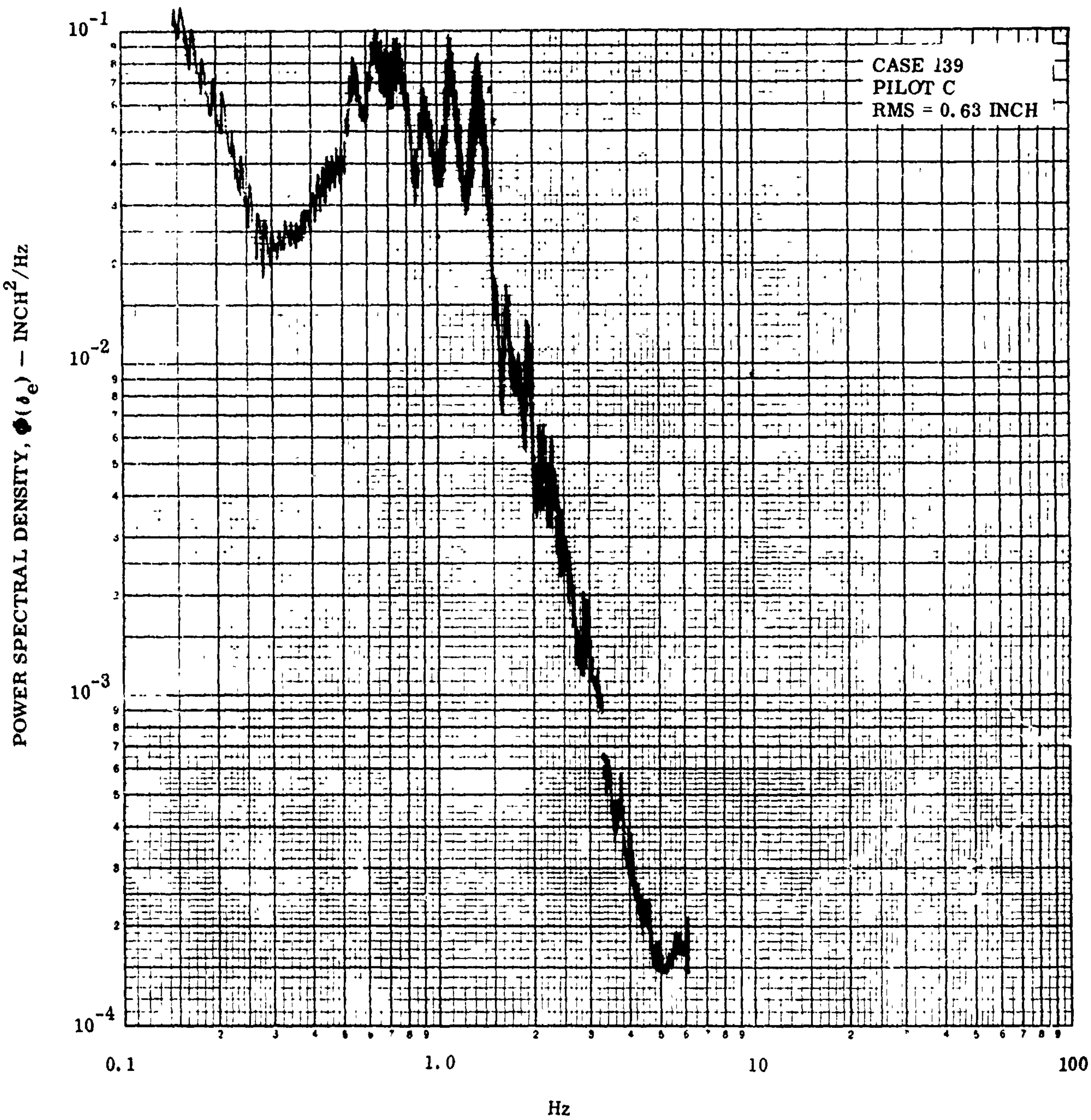

FIGURE 71. STICK POSITION POWER SPECTRAL DENSITY DISTRIBUTION - PITCH CONTROL

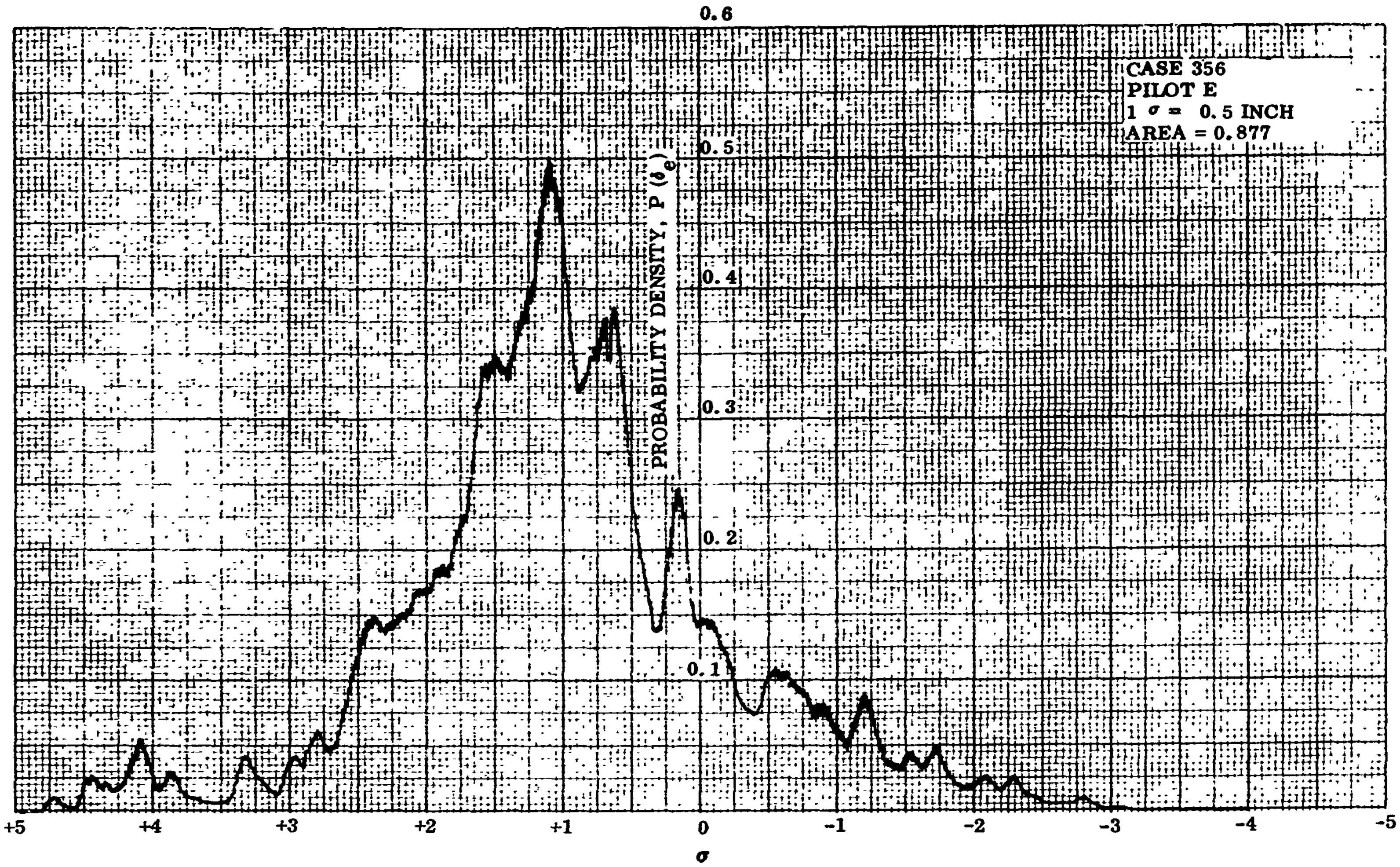

FIGURE 72. STICK POSITION PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

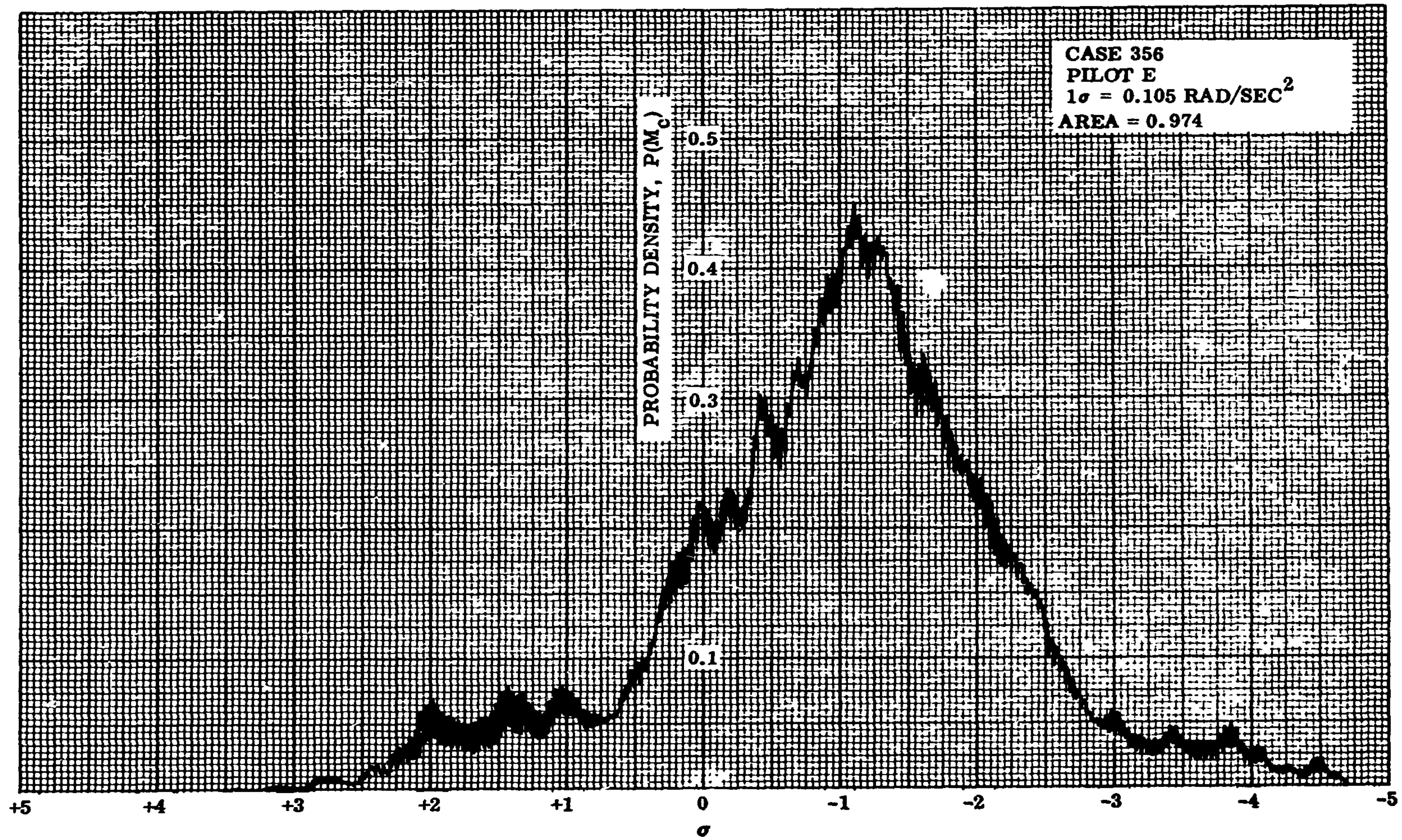

FIGURE 73. INPUT PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

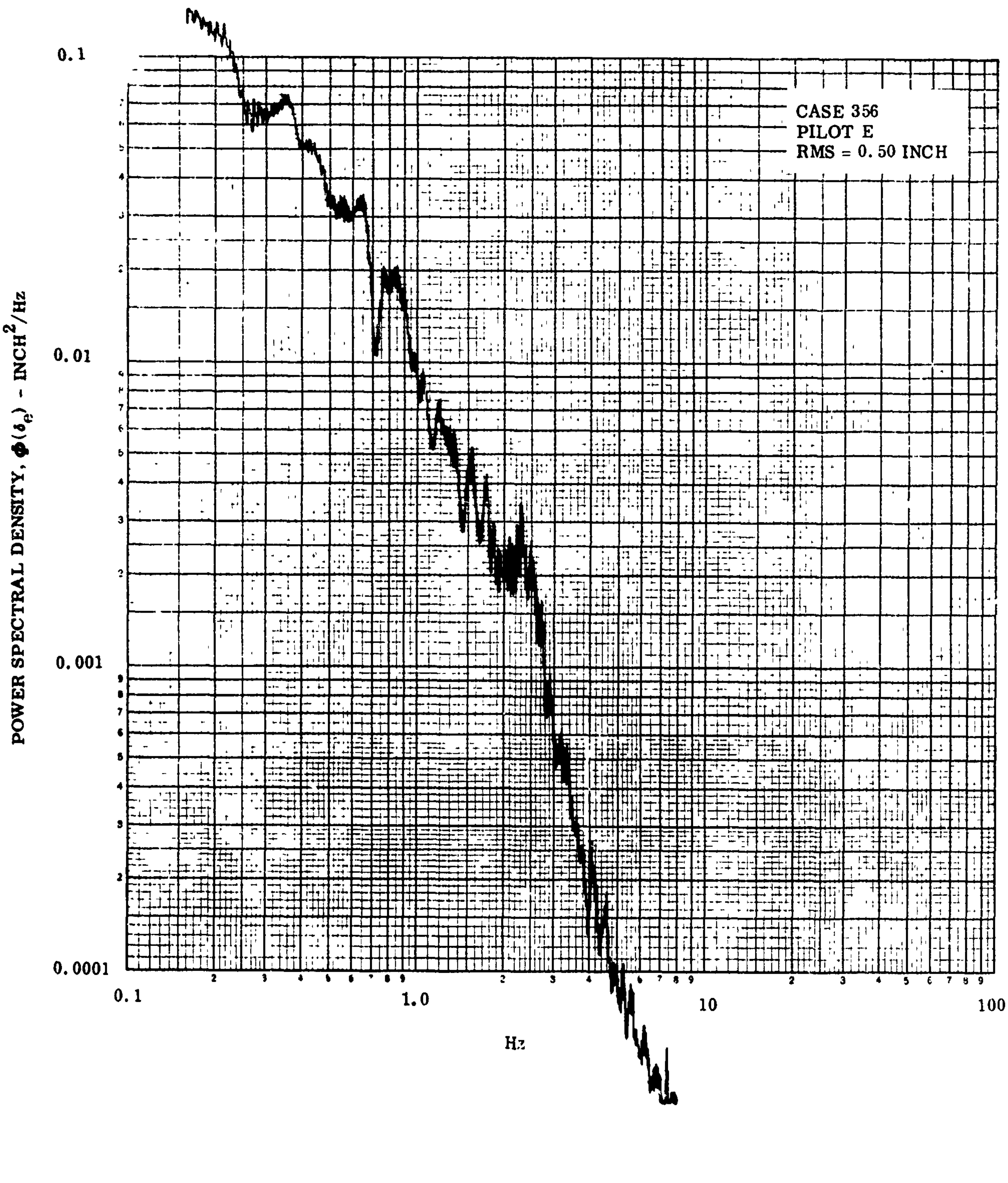

FIGURE 74. STICK POSITION POWER SPECTRAL DENSITY DISTRIBUTION-PITCH CONTROL

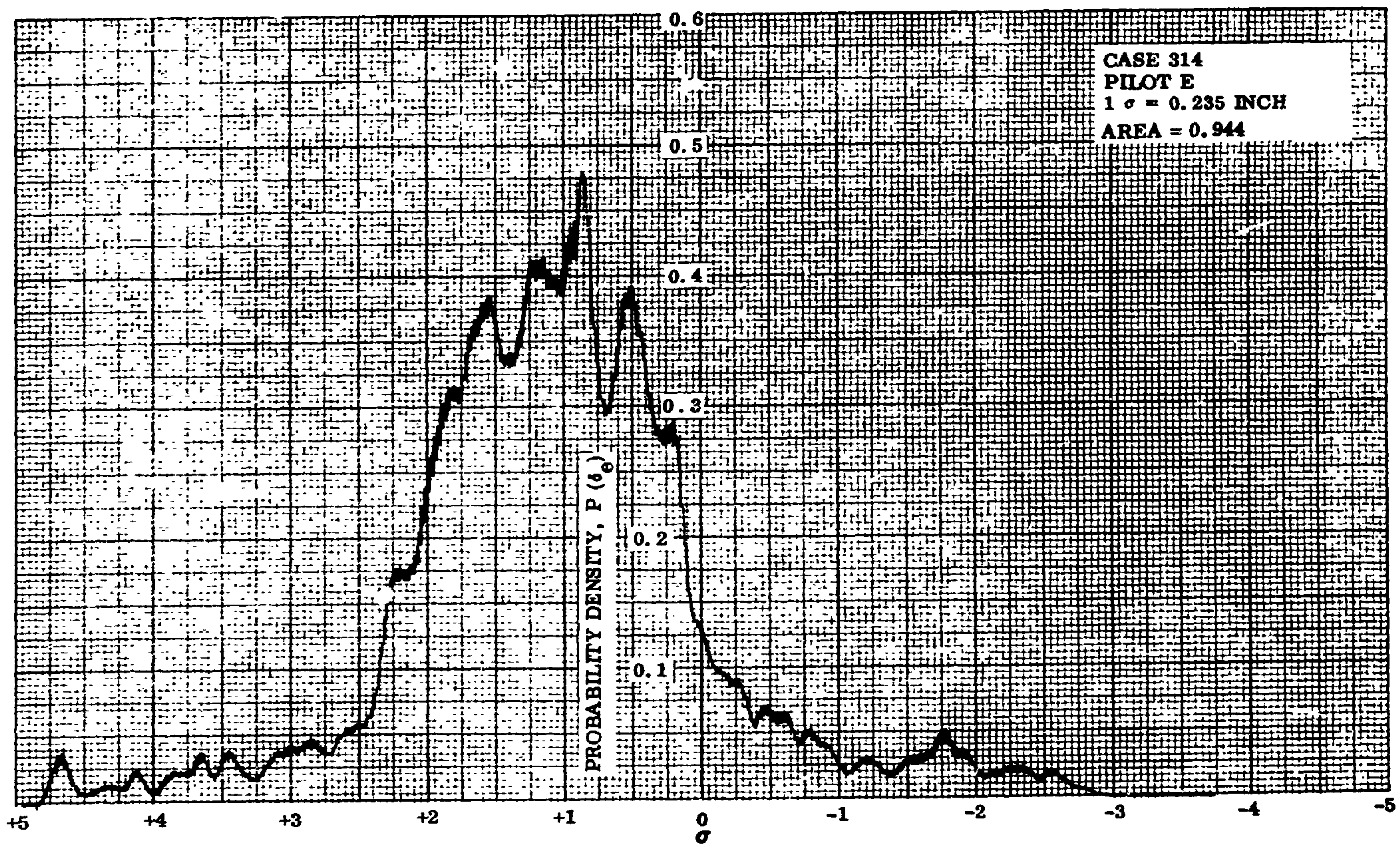

FIGURE 75. STICK POSITION PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

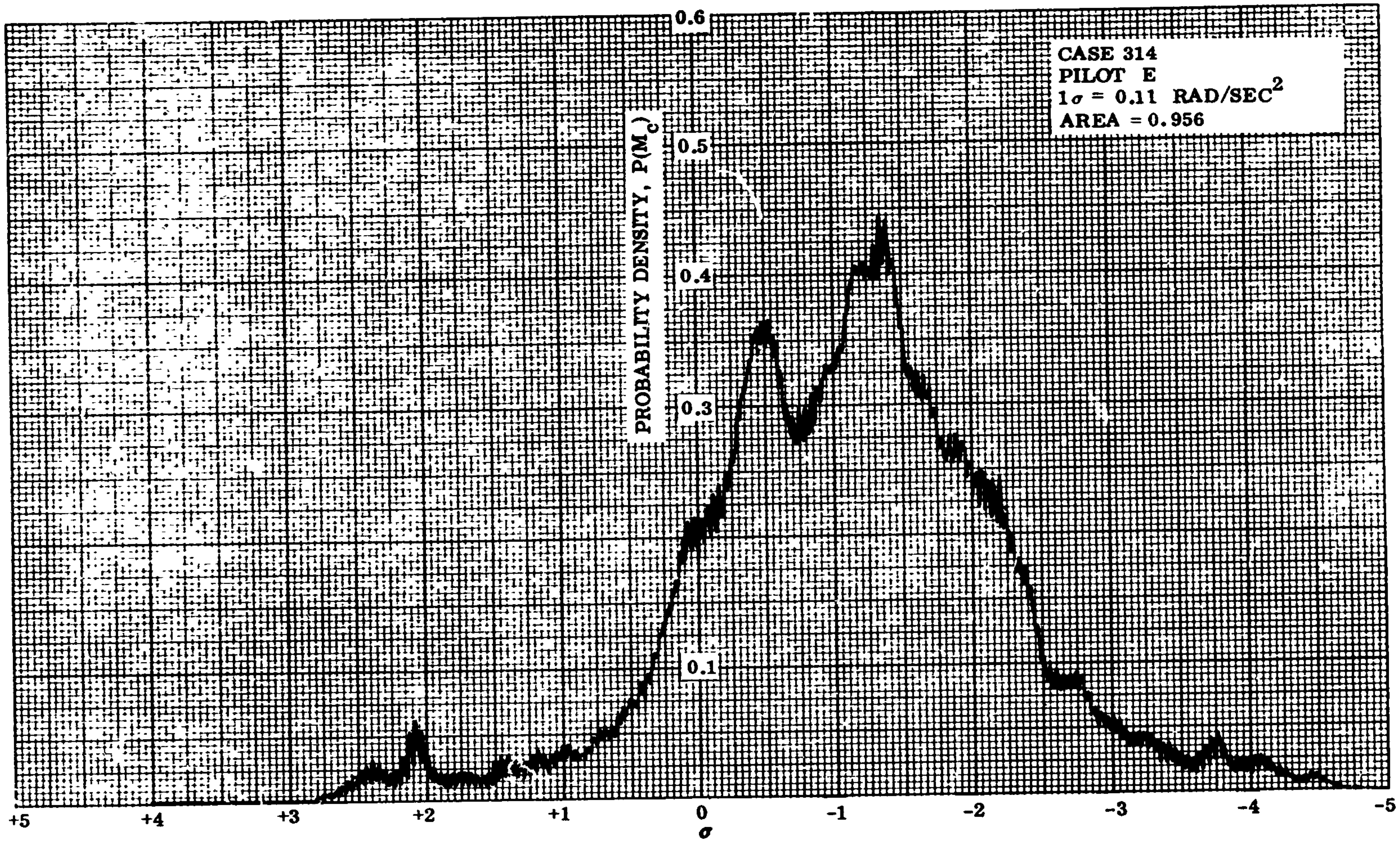

FIGURE 76. INPUT PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

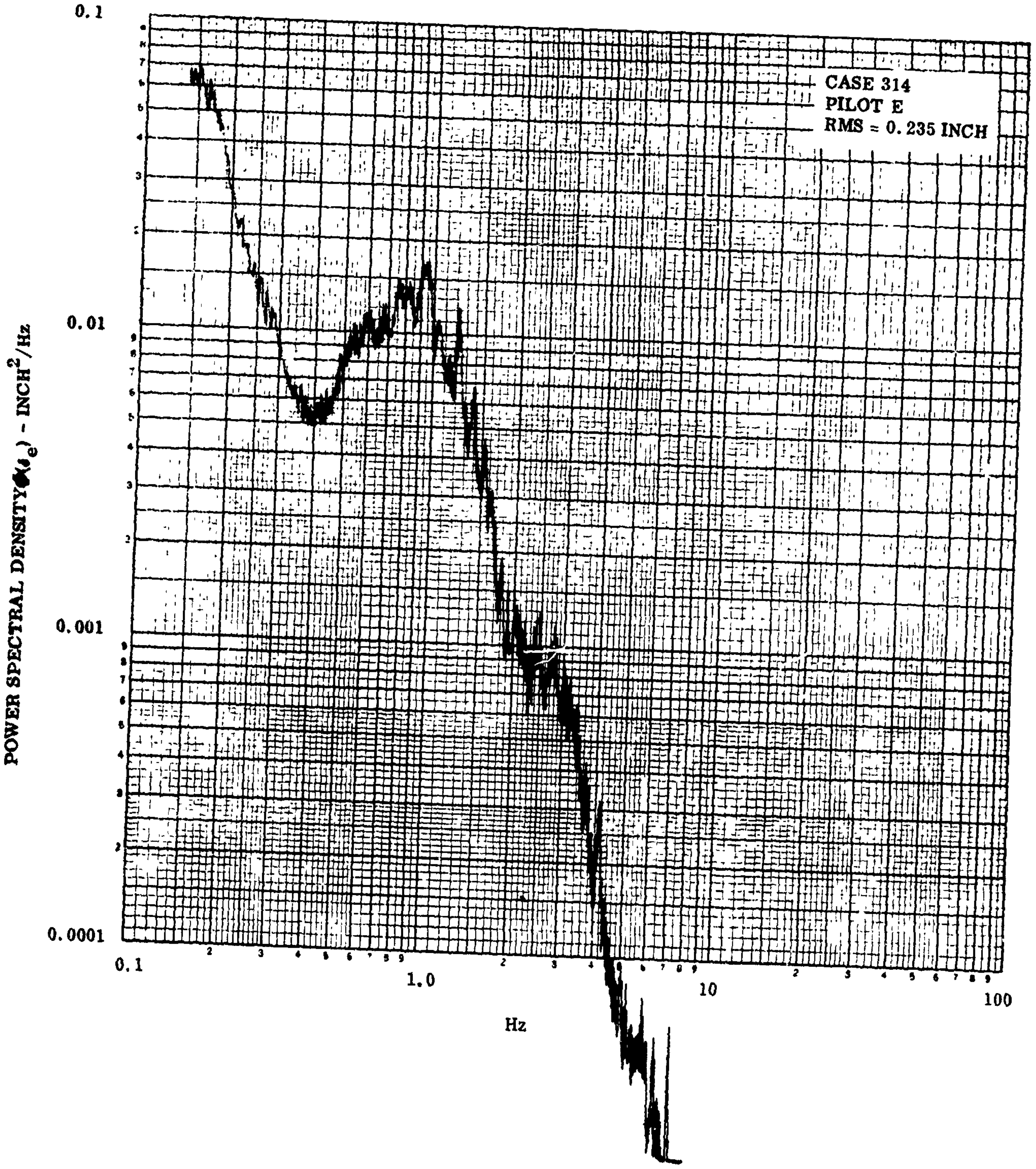

FIGURE 77. STICK POSITION POWER SPECTRAL DENSITY DISTRIBUTION - PITCH CONTROL

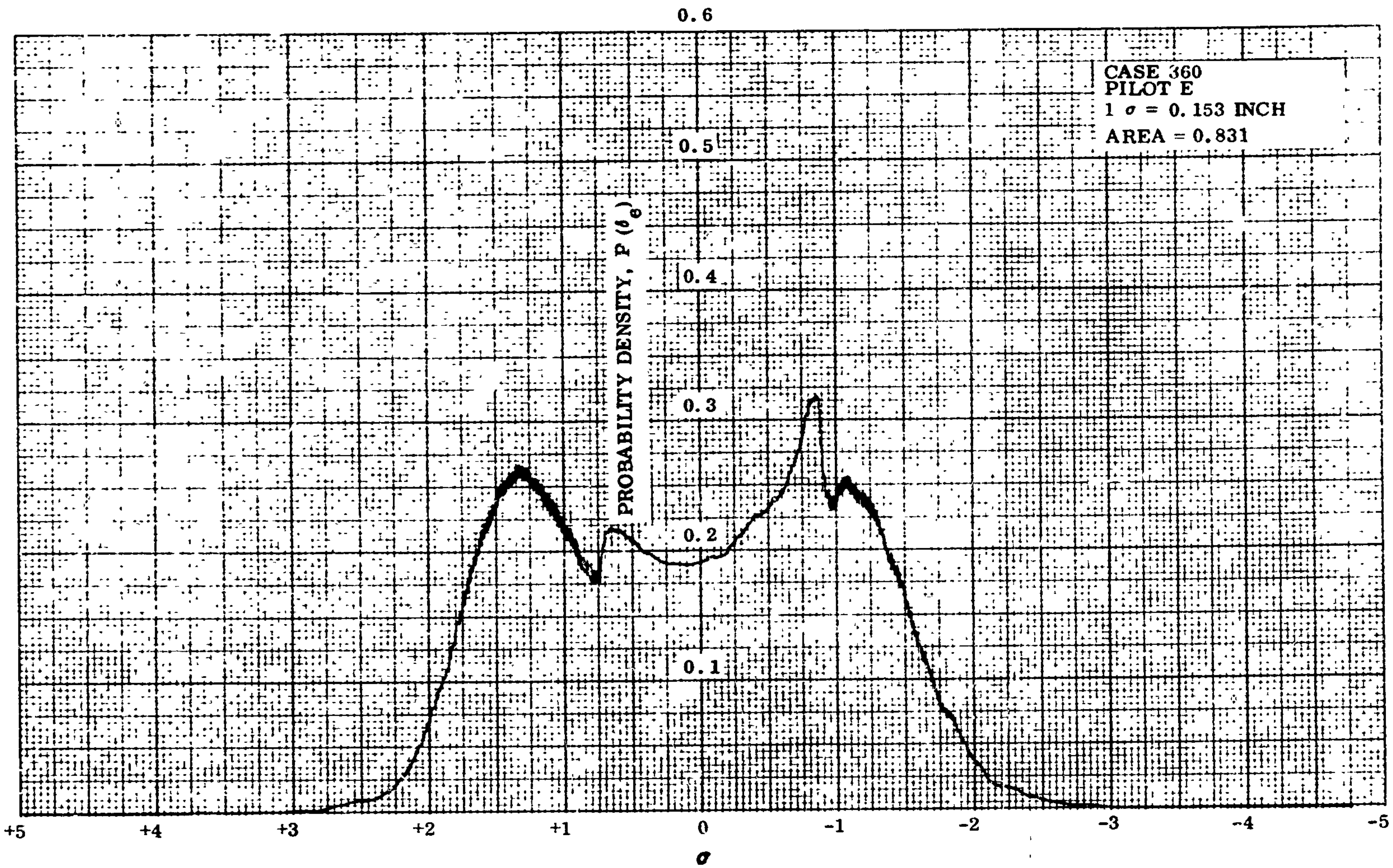

FIGURE 78. STICK POSITION PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

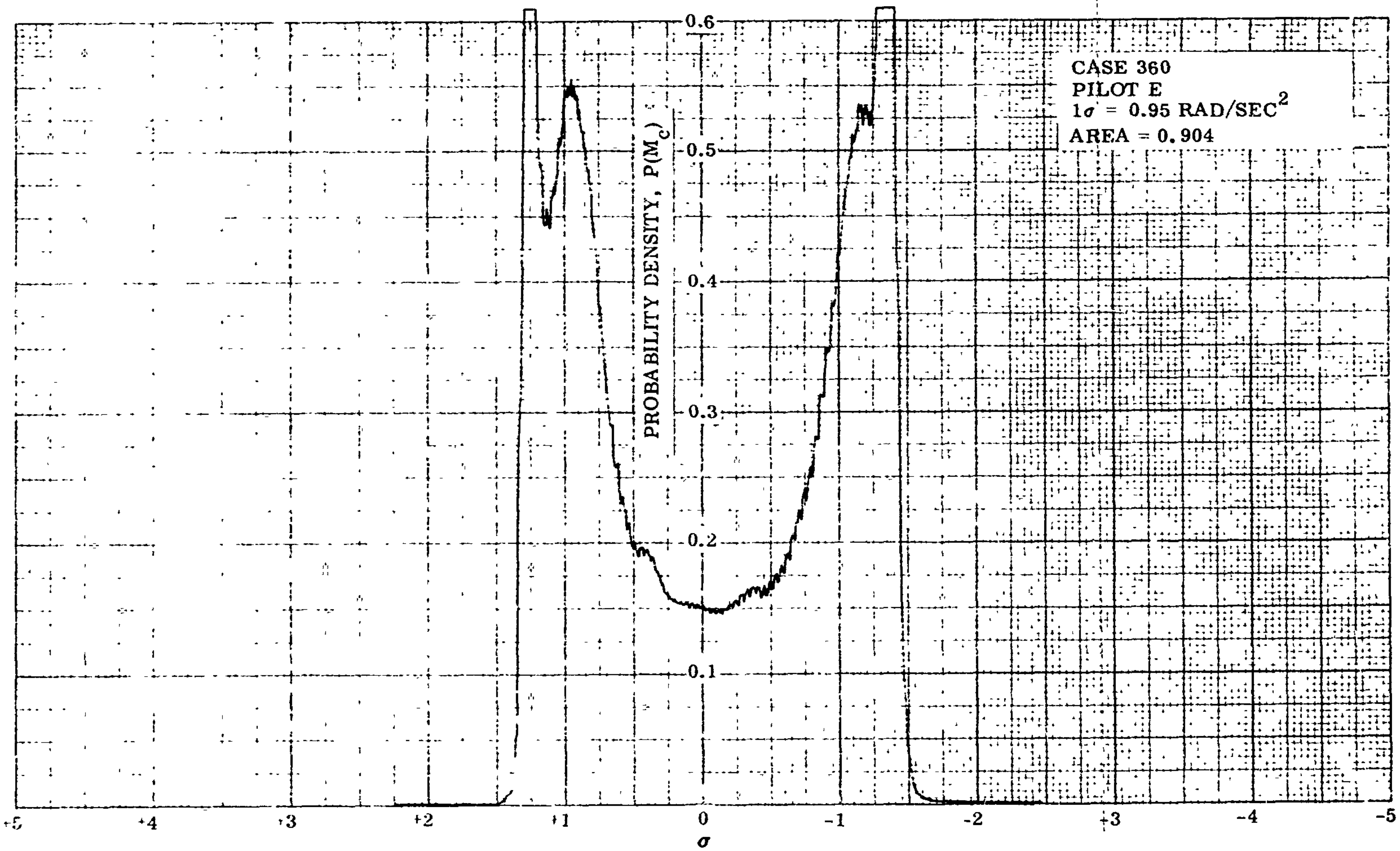

FIGURE 79. INPUT PROBABILITY DENSITY DISTRIBUTION - PITCH CONTROL

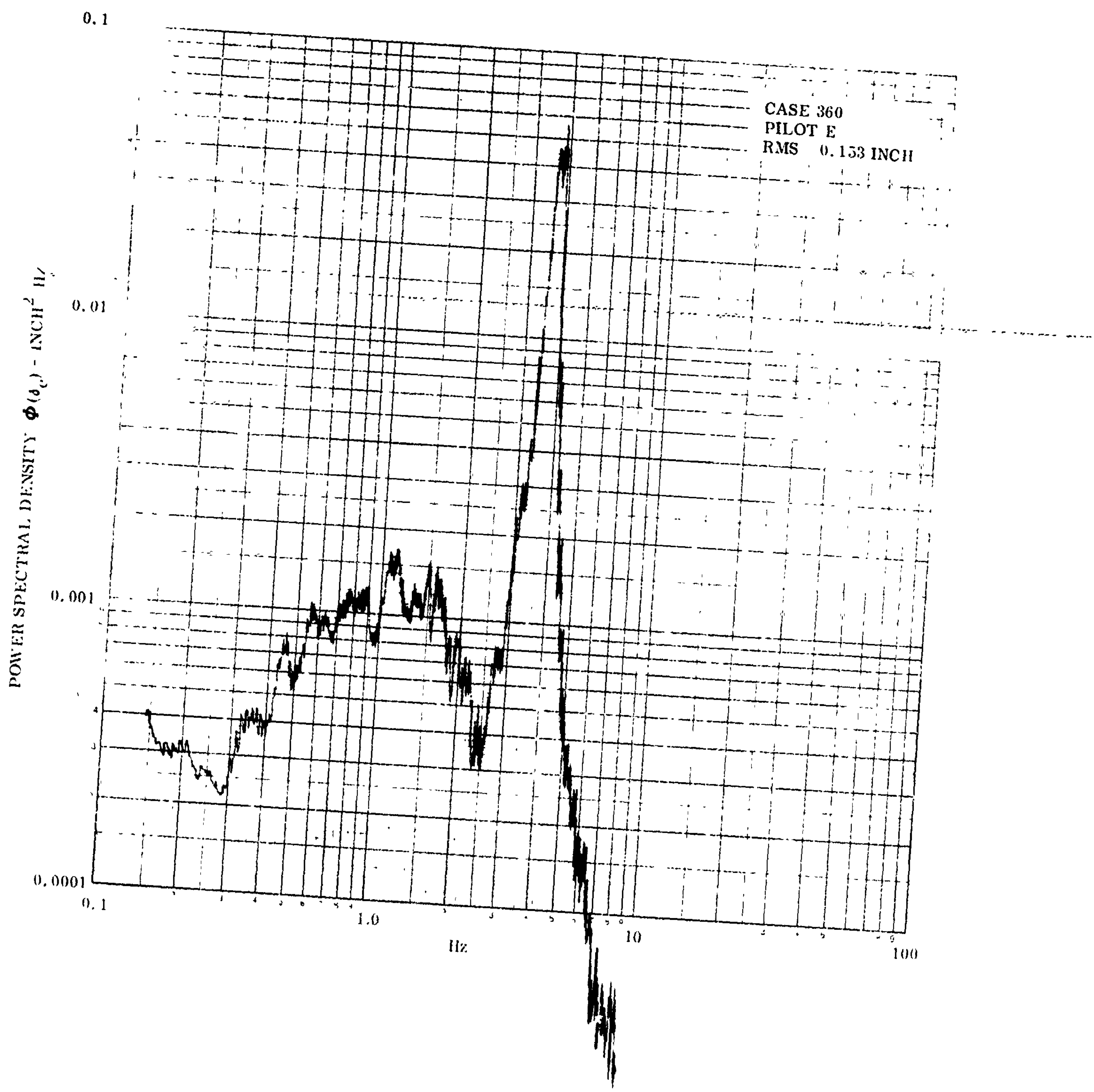

FIGURE 80. STICK POSITION POWER SPECTRAL DENSITY DISTRIBUTION - PITCH CONTROL

APPENDIX IV

UARL TEST RESULTS

In addition to the experiments reported on in the main body of this report (Volume I, Part I), a program was conducted to compare results obtained by United Aircraft Research Laboratories (UARL) on a fixed-base simulator with those obtained by the same pilot on a different fixed-base simulator and then on a moving-base simulator.

Table X contains the values of the stability derivatives and corresponding root locations for the configurations examined by the UARL pilot. These configurations were taken from UARL Report F910482-12 (AFFDL-TR-67-152). The configurations were examined in the Northrop Norair Rotational Flight Simulator in both the fixed-base and moving-base modes.

For the precision hover evaluations (PH configurations), the lateral derivatives were as follows:

$L_v g = -0.1$	$L_\phi = 0$
$Y_v = -0.1$	$L_\delta = 0.301$
$L_p = -3$	

For the roll evaluations (R configurations), the longitudinal and directional derivatives were:

$M_u g = 0.67$	$M_\delta = 0.431$
$X_u = -0.1$	$N_v = 0..002$
$M_q = -3$	$N_r = -1$
$M_\theta = 0$	$N_\delta = 0.2$

TABLE X. UARL CONFIGURATIONS

CASE	X_u	$M_u g$	M_q	M_θ	λ	$\zeta\omega_n$	ω_n	ζ	ω_D
PH10	-0.1	0.67	-1	0	0.138	-0.014	0.696	-0.020	0.696
PH11	-0.1	0.67	-3	0	3.07	0.027	0.466	0.058	0.465
PH12	-0.1	0.67	-5	0	5.03	0.073	0.365	0.200	0.353
P25	-0.3	1.00	-1	0	1.53	-0.115	0.808	-0.142	0.800
P28	-0.3	1.00	-4	0	4.06	0.117	0.496	0.236	0.482
CASE	Y_v	$L_v g$	L_p	L_ϕ					
R25	-0.1	-0.67	-1	0	1.38	-0.139	0.696	-0.200	0.682
R26	-0.1	-0.67	-2	0	2.15	-0.026	0.557	-0.047	0.556
R27	-0.1	-0.67	-3	0	3.07	0.013	0.466	0.028	0.466
R28	-0.1	-0.67	-4	0	4.04	0.029	0.406	0.071	0.405

For the pitch evaluations (P configurations), the lateral and directional derivatives were:

$L_v g$	$= -0.1$	L_δ	$= 0.301$
Y_v	$= -0.1$	N_v	$= 0.002$
L_p	$= -3$	N_r	$= -1$
L_ϕ	$= 0$	N_δ	$= 0.2$

The PH configurations used four degrees of freedom (no directional or height degrees). The R and P configurations used five degrees of freedom (no height degree). Configuration PH 11 was also evaluated moving base with six degrees of freedom.

For the precision hovering experiments, rms data were recorded for u, q, δ_e, u_{gust}, x, and θ based on 100-second runs. Mean wind data also were recorded. It was intended that no steady wind be present, but due to the random nature of the turbulence, some mean wind would be unavoidable over any finite length of run. In addition, it appeared that the noise generator may have had a slight bias in that the mean winds for the 100-second runs were predominately negative in sign.

For each of the precision hovering configurations, pilot ratings were given. For the pitch and roll evaluation experiments, control sensitivity and pilot ratings were recorded.

PRECISION HOVER MANEUVER

A series of 100-second hovering experiments was performed in which the pilot attempted to maintain hovering position at a reference point in the presence of turbulence but without steady winds. A pitch control sensitivity was selected by the pilot as optimum for performing the precision hovering task. At the conclusion of each series of 100-second runs, the pilot assigned a pilot rating to the configuration using both the Revised Rating Scale (see Figure 81) and the original Cooper Pilot Rating Scale (see Figure 82).

PITCH AND ROLL EVALUATION MANEUVERS

A series of hovering and low-speed maneuvering experiments was performed in which the pilot attempted to maintain hovering position at a reference point, and maneuver about the reference point in the presence of turbulence but without steady winds. As optimum for the task, the pilot selected pitch control sensitivity for the P configurations and a roll control sensitivity for the R configurations. At the conclusion of each run, the pilot assigned a pilot rating to the configuration using both the Revised Pilot Rating Scale and the original Cooper Pilot Rating Scale.

CONTROLLABLE CAPABLE OF BEING CONTROLLED OR MANAGED IN CONTEXT OF MISSION, WITH AVAILABLE PILOT ATTENTION	ACCEPTABLE MAY HAVE DEFICIENCIES WHICH WARRANT IMPROVEMENT, BUT ADEQUATE FOR MISSION. PILOT COMPENSATION, IF REQUIRED TO ACHIEVE ACCEPTABLE PERFORMANCE, IS FEASIBLE.	SATISFACTORY MEETS ALL REQUIREMENTS AND EXPECTATIONS, GOOD ENOUGH WITHOUT IMPROVEMENT CLEARLY ADEQUATE FOR MISSION.	EXCELLENT, HIGHLY DESIRABLE	A1
			GOOD, PLEASANT, WELL BEHAVED	A2
			FAIR. SOME MILDLY UNPLEASANT CHARACTERISTICS. GOOD ENOUGH FOR MISSION WITHOUT IMPROVEMENT.	A3
		UNSATISFACTORY RELUCTANTLY ACCEPTABLE. DEFICIENCIES WHICH WARRANT IMPROVEMENT. PERFORMANCE ADEQUATE FOR MISSION WITH FEASIBLE PILOT COMPENSATION.	SOME MINOR BJT ANNOYING DEFICIENCIES. IMPROVEMENT IS REQUESTED. EFFECT ON PERFORMANCF IS EASILY COMPENSATED FOR BY PILOT.	A4
			MODERATELY OBJECTIONABLE DEFICIENCIES. IMPROVEMENT IS NEEDED. REASONABLE PERFORMANCE REQUIRES CONSIDERABLE PILOT COMPENSATION.	A5
			VERY OBJECTIONABLE DEFICIENCIES. MAJOR IMPROVEMENTS ARE NEEDED. REQUIRES BEST AVAILABLE PILOT COMPENSATION TO ACHIEVE ACCEPTABLE PERFORMANCE.	A6
	UNACCEPTABLE DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT. INADEQUATE PERFORMANCE FOR MISSION EVEN WITH MAXIMUM FEASIBLE PILOT COMPENSATION.		MAJOR DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT FOR ACCEPTANCE. CONTROLLABLE. PERFORMANCE INADEQUATE FOR MISSION, OR PILOT COMPENSATION REQUIRED FOR MINIMUM ACCEPTABLE PERFORMANCE IN MISSION IS TOO HIGH.	U7
			CONTROLLABLE WITH DIFFICULTY. REQUIRES SUBSTANTIAL PILOT SKILL AND ATTENTION TO RETAIN CONTROL AND CONTINUE MISSION.	U8
			MARGINALLY CONTROLLABLE IN MISSION. REQUIRES MAXIMUM AVAILABLE PILOT SKILL AND ATTENTION TO RETAIN CONTROL.	U9
UNCONTROLLABLE CONTROL WILL BE LOST DURING SOME PORTION OF MISSION.			UNCONTROLLABLE IN MISSION.	10

FIGURE 81. REVISED PILOT RATING SCALE

	ADJECTIVE RATING	NUMERICAL RATING	DESCRIPTION	PRIMARY MISSION ACCOMPLISHED?	CAN BE LANDED
NORMAL OPERATION	SATISFACTORY	1	EXCELLENT, INCLUDES OPTIMUM	YES	YES
		2	GOOD, PLEASANT TO FLY	YES	YES
		3	SATISFACTORY, BUT WITH SOME MILDLY UNPLEASANT CHARACTERISTICS	YES	YES
EMERGENCY OPERATION	UNSATISFACTORY	4	ACCEPTABLE, BUT WITH UNPLEASANT CHARACTERISTICS	YES	YES
		5	UNACCEPTABLE FOR NORMAL OPERATION	DOUBTFUL	YES
		6	ACCEPTABLE FOR EMERGENCY CONDITION ONLY*	DOUBTFUL	YES
NO OPERATION	UNACCEPTABLE	7	UNACCEPTABLE EVEN FOR EMERGENCY CONDITION*	NO	DOUBTFUL
		8	UNACCEPTABLE - DANGEROUS	NO	NO
		9	UNACCEPTABLE - UNCONTROLLABLE	NO	NO
	UNPRINTABLE	10	"MOTIONS POSSIBLY VIOLENT ENOUGH TO PREVENT PILOT ESCAPE"		

* (Failure of a stability augmenter)

FIGURE 82. ORIGINAL COOPER SCALE

TURBULENCE

The turbulence level was set at 5.1 ft/sec rms in the axis under evaluation, and 1.3 ft/sec rms in the other axis.

DATA

For the precision hover cases, Table XI lists the average rms values for θ, q, x, u, and δ_e; the pilot-selected control sensitivities; and the pilot ratings.

The rms values of each quantity for each run were averaged for the total number of runs. Mean wind corrections were applied to pitch attitude and control motion in accordance with UARL Report F910482-12. Mean wind correction was also applied to the turbulence and then all of the rms values were corrected to the nominal rms turbulence level.

These calculations have been performed independently by both Norair and UARL, and some discrepancies,due to details of the calculation procedures, may exist in the resulting values as reported by each company.

For the R and P evaluation cases, Table XII lists the pilot-selected control sensitivities and the pilot ratings.

The precision hover data show fairly good agreement between the Norair simulator in the moving-base configuration and the UARL fixed-base simulator. The comparison of the UARL simulator with the Norair simulator in the fixed-base configuration was not as good. The Norair simulator display did not provide a precise visual translational fore-and-aft position cue to the pilot whereas the cockpit display in the UARL simulator did. Apparently the motion cue provided by the Norair simulator supplemented the visual cue to a considerable extent. The control sensitivities selected were quite similar for the Norair moving-base simulator and the UARL simulator. Pilot ratings averaged slightly higher for the Norair simulator but were within one point on the rating scale of the UARL values. Pitch attitude and pitch rate rms values were very similar. Fore-and-aft position rms was a little higher for the Norair simulator, as was the fore-and-aft velocity. Stick activity was slightly less in the Norair simulator.

For the R and P evaluations, the control sensitivity selected tended to be about the same or somewhat lower in the Norair moving-base simulator, and definitely higher in the Norair fixed-base simulator. Pilot ratings were very similar for the Norair moving-base simulator and the UARL simulator, and consistently higher in the Norair fixed-base simulator.

TABLE XI. COMPARISON OF RESULTS OF PRECISION HOVER TESTS

CASE	SIMULATOR	PILOT *	M_δ	COOPER RATING	REVISED RATING	σ_θ RAD	σ_q RAD/SEC	σ_x FT	σ_u FT/SEC	σ_{δ_e} IN
PH10	Norair RFS Fixed	B	0.563	7.0	8.0	0.0477	0.0738	3.21	1.519	0.433
	Norair RFS Moving	B	0.379	5.0	5.0	0.0375	0.0653	1.79	0.895	0.632
	UARL	A	0.369	4.25	-	0.0373	0.0630	1.51	0.986	0.704
	UARL	B	0.369	4.25	-	0.0335	0.0584	1.17	0.802	0.716
PH11	Norair RFS Fixed	B	0.750	5.0	5.0	0.0408	0.0542	3.22	1.323	0.324
	Norair RFS Moving	B	0.545	4.0	4.0	0.0330	0.0491	1.68	0.836	0.446
	Norair RFS Moving (6 DOF)	B	0.418	-	-	0.0402	0.0518	2.22	0.927	0.599
	UARL	A	0.431	3.0	-	0.0353	0.0515	1.45	0.976	0.612
	UARL	B	0.431	3.0	-	0.0330	0.0495	1.08	0.808	0.625
PH12	Norair RFS Fixed	B	0.657	5.5	6.0	0.0387	0.0464	3.11	1.295	0.418
	Norair RFS Moving	B	0.586	3.0	3.0	0.0334	0.0449	1.80	0.835	0.498
	UARL	A	0.493	3.0	-	0.0307	0.0422	1.32	0.815	0.584
	UARL	B	0.493	3.25	-	0.0304	0.0426	1.10	0.753	0.607

*Pilot designations A and B refer to pilot designations in UARL Report F910482-12 and are not the same pilots as A and B in the main body of this report.

TABLE XII. COMPARISON OF RESULTS OF
R AND P EVALUATIONS

CASE	SIMULATOR	PILOT*	M_δ	L_δ	COOPER RATING	REVISED RATING
R25	Norair RFS Fixed	B	-	0.316	7.0	8.0
	Norair RFS Moving		-	0.257	5.0	5.0
	UARL	A	-	0.238	5.5	-
		B	-	0.253	5.0	-
R26	Norair RFS Fixed	B	-	0.422	5.5	6.0
	Norair RFS Moving		-	0.296	4.0	4.0
	UARL	A	-	0.306	4.25	-
		B	-	0.289	4.0	-
R27	Norair RFS Fixed	B	-	0.468	4.0	4.5
	Norair RFS Moving		-	0.250	3.5	4.0
	UARL	A	-	0.338	3.25	-
		B	-	0.348	3.25	-
R28	Norair RFS Fixed	B	-	0.521	3.5	4.0
	Norair RFS Moving		-	0.286	3.0	3.0
	UARL	A	-	0.399	3.25	-
		B	-	0.396	3.0	-
P25	Norair RFS Fixed	B	0.528	-	6.5	7.0
	Norair RFS Moving		0.275	-	5.5	6.0
	UARL	A	0.383	-	6.0	-
		B	0.387	-	5.5	-
P28	Norair RFS Fixed	B	0.630	-	4.0	4.0
	Norair RFS Moving		0.372	-	3.0	3.0
	UARL	A	0.510	-	3.75	-
		B	0.512	-	3.75	-

*See note in Table II.

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13 ABSTRACT

An investigation of VTOL longitudinal and lateral handling qualities in hovering and low-speed maneuvering flight was conducted on a moving-base simulator. The simulator included an external display, and the task performed by the participating pilots was a visual rather than an instrument task. Pertinent longitudinal and lateral stability derivatives were varied in a wide range of test configurations. Most of the cases investigated included the effects of steady winds and turbulence. For part of the program, stick force gradients existed on the simulator control stick; for part of the program, they did not. For most of the cases, the pilot selected optimum control sensitivities. In all cases a pilot rating and pilot comments were given. Other data resulting from the simulations include probability density and power spectral density analyses. Pilot performance for part of the task also was calculated.
It appeared that the most significant parameters affecting pilot rating were the drag parameters because of the large attitude changes that resulted when compensating for steady wind and when maneuvering. Speed stability parameters did not seem to have a clear-cut effect on handling qualities. Steady winds and gusts had a strong influence on pilot acceptability when high drag factors were present. Stick force gradients did not, when steady winds were absent. Control sensitivity seemed to be more a matter of personal pilot preference than the configuration. This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of AFFDL (FDCC).

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